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AN ASSESSMENT OF ATLANTIC REGION WATER QUALITY BRANCH TOXIC CHEMICAL DATA 1980-1987

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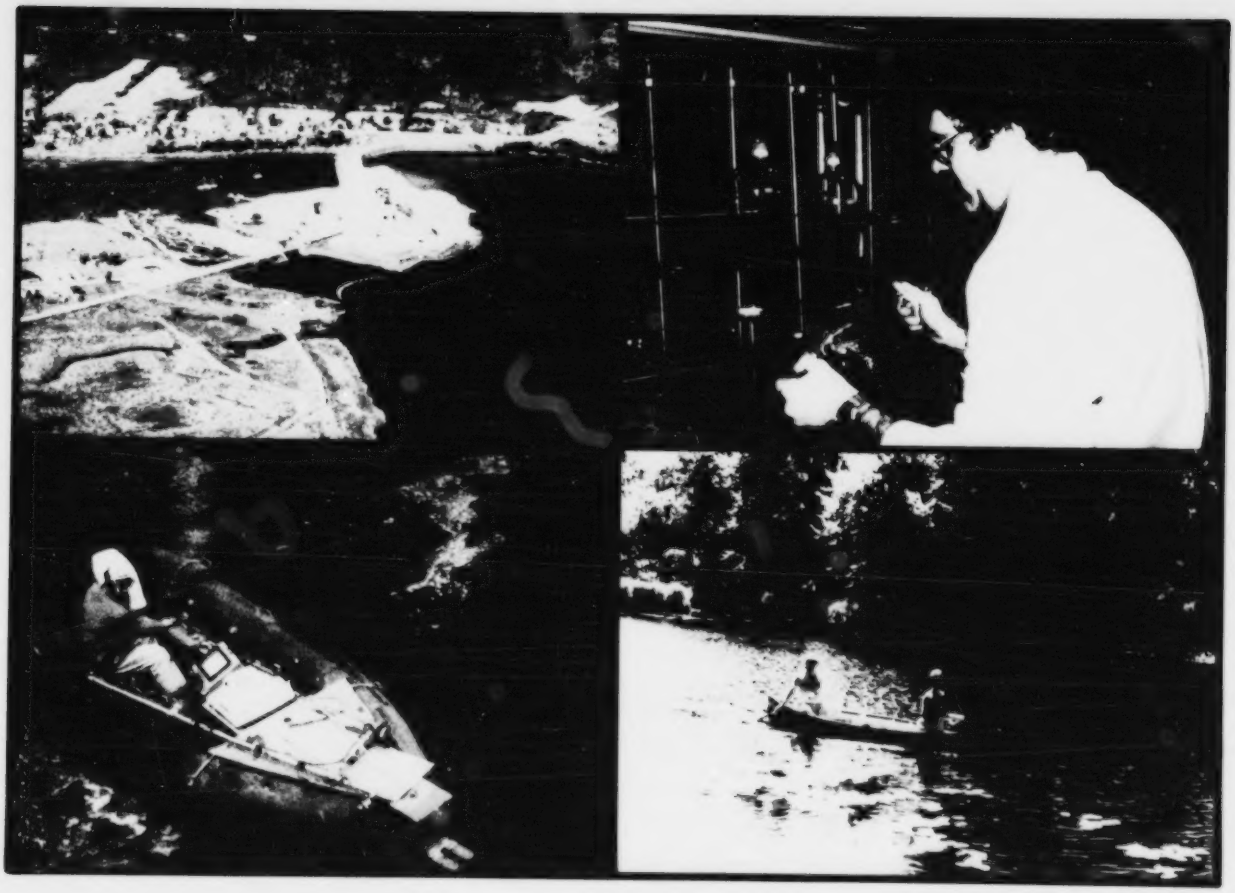

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AN ASSESSMENT OF ATLANTIC REGION

WATER QUALITY BRANCH

TOXIC CHEMICAL DATA

1980-1987

IW/L-AR-WQB-88-140

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ABSTRACT

This document presents data encompassing various toxic organic chemical surveys, conducted by the Water Quality Branch, Atlantic Region for the period 1980 to 1987. Water, bottom sediment and biota results are presented for compounds that were frequently observed in the aquatic ecosystem of the region. The ubiquitous compounds alpha-BHC and fluoranthene were observed in water, while several polyaromatic hydrocarbons, polychlorinated biphenyls, and the persistent organochlorine DDT and its metabolites were reported in sediments. Biota from the region indicated the presence of DDT, its metabolites, and in some cases PCB's. The harbours of Atlantic Canada were the most contaminated areas sampled in the region.

Results are also presented for those classes of chemicals that are less frequently observed. Several in-use biocides were observed on an infrequent basis including the triazine herbicide atrazine, the carbamate insecticides aldicarb, carbaryl, and carbofuran, and the chlorophenoxy acid herbicides 2,4-D and 2,4,5-T. Several organophosphorus insecticides were also noted in surface waters.

The presence of the forestry insecticide fenitrothion has been noted in both surface waters of New Brunswick and in precipitation collectors to monitor off-target fallout and atmospheric drift.

SOMMAIRE

Ce document présente les données provenant de plusieurs études sur des substances chimiques toxiques effectuées par la Direction de la qualité des eaux, région de l'Atlantique, entre 1980 et 1987. Durant ces études, des échantillons aqueux, sédimentaires et biologiques de l'écosystème aquatique régional ont été recueillis pour analyse. Les résultats analytiques, pour les composés fréquement observés dans ces échantillons, sont présentés. L'alpha-BHC et le fluoranthène, deux composés omniprésents, furent observés dans l'eau, pendant que plusieurs hydrocarbures multiaromatiques, des polychlorobiphényles et le DDT, un organochloré persistant, furent détectés dans les sediments. La présence de DDT, ses métabolites et parfois même les PCB, a été révelée dans les échantillons biologiques recueillis dans la région. Les ports maritimes du Canada atlantique furent les endroits les plus contaminés, parmi ceux échantionnés dans la région.

Les résultats, pour d'autre groupes de produits chimiques observés moins fréquemment, sont aussi présentés dans ce rapport. Plusieurs biocides présentement en usage ont été observés sur une base moins régulière. Il s'agit de l'atrazine, un herbicide de la famille des triazines, de l'aldicarbe, le carbaryl et le carbofuran, des insecticides de la famille des carbamates, et les 2,4-D et 2,4,5-T, des herbicides dérivés de l'acide chlorophénoxy. Plusieurs insecticides organophosphorés furent aussi détectés dans l'eau de surface.

La présence du fénitrothion, un insecticide forestier, a été détectés dans l'eau de surface du Nouveau-Brunswick et aussi dans les collecteurs de précipitation. Ces derniers servent à contrôler la retombée hors-cible et la dérive atmosphérique de ce pesticide.

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INTRODUCTION

The Water Quality Branch, Atlantic Region, has actively been investigating water quality in the Atlantic Region since 1965. Belliveau (several references 1981-1987) has summarized the extent and purpose of these studies in each of the four Atlantic provinces. Many monitoring programs have dealt with major ion data, while others included metals and toxic organic chemicals. Each individual project resulted in a report dealing with that project, its data, and cited other supporting observations (Appendix A). Howell (1987) was the first to take the large data base generated by 20 years of water quality monitoring and produce an assessment document dealing with acid precipitation in Atlantic Canada. His "Assessment of LRTAP Acidification of Surface Waters in Atlantic Canada" utilized major ion data spanning several years for surface water throughout the region.

No such broad scope document has been prepared by the Water Quality Branch dealing with toxic chemical data in general, and toxic organics in particular. In excess of 3700 toxic chemical program samples are in the permanent file of the Branch's LABS-11 data management system with each sample representing anywhere from two to fifty parameters. A breakdown of the various parameter groups and the numbers of samples included in each is detailed in Appendix B. In addition to the toxic organic parameters; all water samples were characterized by analysis for physical parameters, major ions, nutrients, and metals, sediments usually had heavy metal analysis performed and biota, lipid content.

This document is not intended to be solely a compendium of the previous authors' work, but rather, an attempt to combine previous work and observations, from a specific period, into one document illustrating the extent and magnitude of toxic organic chemicals in aquatic media of the Atlantic Region. It is also intended to illustrate the extent of Water Quality Branch efforts in monitoring the surface water aquatic system for toxic organic chemicals, and to propose program areas for future endeavours.

METHODOLOGY

Time Frame and Parameter Selection

The time period selected for assessment consists of data generated from 1980 onward. This period was selected so that biases created by changes in analytical methodology and detection limits could be minimized and in most cases eliminated. Detection limits are at present, an order of magnitude lower than the detection limits reported from 1971 to 1975 thus making temporal comparisons difficult. Also, from 1980 to 1987, due to technical improvements, more chemical groups and classes of compounds were investigated, as opposed to the early seventies when the organochlorine group was the principal pesticide class quantitated.

The parameters discussed were divided into two groups based upon the frequency of positive observations reported. The first group consisted of those parameters that were observed frequently in the samples quantitated. The frequency of observations permitted the generation of Box and Whisker diagrams to illustrate the extent of reported levels. The second group, where the majority of the observations were less than detection limit, the parameter is reported as such and the areas of positive results noted.

Within Environment Canada, Conservation and Protection, the Water Quality Branch has operated principally under the Canada Water Act and has targetted water quality guidelines, objectives and the production of baseline data. The Environmental Protection Service on the other hand has traditionally been the enforcement arm of the Service operating within Section 33 of the Fisheries Act dealing directly with industrial point source polluters. As a consequence of these directions, Water Quality Branch data for toxic chemicals and environmental contaminants have often been at the technological limits of the analytical methodologies with many observations of "less than detection limit" being noted. For instance, projects such as the Municipal Drinking Water Sources

Toxic Chemical Survey have resulted in many observations below detection limits while surveys in harbours and estuaries have generally resulted in observations well in excess of detection limits. These programming biases make direct quantitative comparisons difficult but do not preclude use in a qualitative context.

Media

Toxic organic chemical data existed for three principal media: water, bottom sediment and biota. It was decided to sub-divide each group by water type into streams, lakes, estuaries and harbours to minimize the inherent differences of water chemistry with each group. In some cases the majority of the data might have been for lakes, while another chemical group might have had more stream data available. Bottom sediments were likewise divided according to source. Biota consisted primarily of whole fish and in the case of Quebec- Labrador samples, dissected specimens for gonad, liver, and muscle. Considerable data also existed for groundwater and precipitation but only surface water will be discussed in this document.

Data Validation and Handling

All data were obtained through an exhaustive search of the data management system permanent files for the parameters of interest. This usually resulted in a long printout of NAQUADAT station numbers, sample information, and reported observations. Unfortunately this search procedure also resulted in many quality control samples being included. These various spikes and blanks had to be edited from the data sets to eliminate false positive and negative values. It became apparent that several NAQUADAT station numbers were incorrect in that they did not specify any specific sub-basin or location (ex. 00NB00000000) and had to be eliminated. Several spiked samples were included in the incorrect station number group making any use of that data questionable. However,

the benefit of the inconvenience generated by these quality control samples lay in the fact that they illustrated the existence of a quality assurance/quality control program from 1980 onward. This was a secondary factor in selecting the post-1980 observations as the principal source of data, and proved to be of benefit when dealing with low level observations.

After the removal of the aforementioned observations, the data were then sorted by water type (i.e. stream, lake, estuary and harbour). At this point it was observed that there were significantly fewer observations for estuaries and harbours as compared to streams and lakes and it was decided to combine the former data sets into one. It is felt that this was acceptable as they both deal with salt water influenced areas and were often associated.

Each of the media specific sub-groupings was then sorted by sub-basin so that the extent of sampling frequency could be observed. The sub-basin divisions used were those of the Drainage Index of the Water Resources Branch of the Inland Waters Directorate. Spatial biases existed in that some areas (eg. the international reaches of the Saint John River) were more frequently sampled than others. The majority of any data set for New Brunswick consisted of stream data while the majority of Newfoundland data was for lakes and ponds. This made the comparison of sub-basins difficult as water types were not to be combined.

Because of the absence of recurrent sampling sites, temporal variability could not be addressed when dealing with surface water data. Temporal variability is part of an ongoing Water Quality Branch program dealing with toxic organic chemicals in rainfall, wherein two sites have been sampled monthly (since 1980) for precipitation. The results of this work have been reported by Brun (1982, 1983, 1984).

To address spatial differences, data were subdivided, as previously mentioned, by sub-basin, and Box and Whisker diagrams generated to indicate minimum, maximum and median values, together with lower and upper quartile ranges, Figure 1A. It must be cautioned that some sub-basins had fewer than three observations while others had greater than ten thus generating in-basin biases. In some cases a triplicate sample was the only one collected in a basin and would not be truly representative. Also, any site that had only two observations would not be graphed as a minimum of three were required to generate a Box and Whisker plot. Nevertheless, this method of handling the observations is felt to facilitate the presentation of the large amount of data available.

When dealing with the retrieved toxic organic chemical data, there was an inherent requirement to handle observations that were reported as "less than" a specified detection limit. In order to graphically present "less than" observations, the original data tables were edited and all less than detection limit values were recorded as 90 percent of the detection limit. Therefore, a reported value of L0.001 μg/L was changed to 0.0009 μg/L, enabling the data to be manipulated by the RS1 data handling package. Such handling allowed observations below detection limit to be included in the data analysis while still maintaining a desirable level for "less than detection" notation. Values reported as less than detection limit do not imply that a target chemical was not present in an environmental sample but rather that it was not detected. Detection limits are a function of sample size, analytical extraction methodologies, instrumentation, detector sensitivity, analytical column selectivity, background noise, and co-extractives. Through field and laboratory quality assurance/quality control procedures and documentation of analytical methodologies, confidence in the detection limit is established. Thus, observations reported as less than a given detection limit are valid observations representing the documented technology used to obtain the values and the confidence level of the analytical methodology.

Quality Assurance/Quality Control

An assessment document spanning 7 years of analytical data is totally dependent upon the quality assurance/quality control (QA/QC) practices used to generate the original data of the day. Without question, complex analyses require extensive QA/QC protocols. The presence of QA/QC samples in the initial data retrieval indicated that, the number of control samples were higher from 1984 to 1987, but a QA/QC aspect was present from 1980 to 1984. The details of the quality assurance aspect for each project is elucidated in each project specific report. In summary, the QA/QC protocols for toxic organic chemical programs have consisted of field blanks, field spiked distilled water, and field spiked environmental samples, while the Analytical Services Division laboratory routinely processed method and reagent blanks, and laboratory spikes of distilled water. Spiking solutions were prepared by the laboratory staff to represent a cross-section of each chemical group to be quantitated at levels that would be encountered in environmental samples. For those groups where less than detection limit values were frequently reported, spikes were usually prepared at levels of the same order of magnitude as the detection limit. The Analytical Services Division also routinely participates in inter-laboratory and intra-laboratory quality assurance audits for toxic organic chemicals, major ion, metal, and nutrient analyses.

With respect to this specific report, QA/QC consisted primarily of manually verifying any incorrect station numbers or anamolous values in data tables, by cross referencing with the original sample log-in book. It was also necessary in a few cases to confirm observations by referring to the individual analyst's result records, or chromatograms.

RESULTS AND DISCUSSION

Frequently Observed Parameters

Five chemical groups were frequently reported in the media of the surface waters of the Atlantic Region: organochlorine insecticides, polychlorinated biphenyls, polyaromatic hydrocarbons, phthalic acid esters and triazine herbicides. Each will be discussed according to aquatic type and media. Box and Whisker diagrams have been prepared for each group where there was a minimum of three sub-basin observations. Though this practice is not statistically representative of each sub-basin it does illustrate the breadth of Water Quality Branch monitoring and can delineate data deficiencies.

Organochlorine Insecticides and Polychlorinated Biphenyls

The organochlorine group of chemicals including polychlorinated biphenyls (PCBs) are solely a man-made environmental issue. The most widely reported effect of past organochlorine use is the well documented case of the peregrine falcon and its diminished population due to contamination of the peregrine food sources by DDT (1,1,1-trichloro-2,2-BIS(4-chlorophenyl) ethane). Though DDT has been known since 1874, its insecticidal properties were not reported until 1939 when its effectiveness was demonstrated during World War II for the control of typhus and malaria. It was not until the early 1950's that it was discovered that chlorinated hydrocarbons were having an effect on the population of the perigrine falcon and other raptors (Hodges 1972).

Due to the past widespread use of the organochlorine group the Water Quality Branch has performed a greater number of analyses for this group than for any other toxic organic chemical. As a consequence, from 1980 to 1987, 782 water, 476 sediments and 301 biota samples have been analyzed. Following data validation 622,

463, and 301 samples remained for interpretation. Table 1 lists the organochlorine insecticides routinely quantitated by the Water Quality Branch in water, sediment and biota.

Of the organochlorines insecticides quantitated only alpha-BHC and lindane (gamma-BHC) were observed in surface waters. There were isolated single trace amounts reported for some of the other OC's but there were not enough observations to plot Box and Whisker diagrams. Of the eight isomers of hexachlorocyclohexane (HCH) only gamma-BHC (lindane) displays any significant insecticidal activity (CCREM 1987). Alpha-BHC is the principal isomer present in technical mixtures and has been more prevalent in waters of the Atlantic Region. The widespread observations of HCH isomers is partly due to their volatile nature as they have been used as fumigants (Brooks 1979).

Figure 1 illustrates that samples taken from rivers and streams had the fewest observations for organochlorines with trace levels reported for alpha-BHC in basins AD, AH, AJ, BJ, CB, ZG, ZK, and ZN. Somewhat higher alpha-BHC levels were observed in basins DC, DD, DG, DP, YQ and YS. With the exception of DP, median values were within three times the detection limit of 0.001 μg/L indicating that alpha-BHC was present at very low levels.

Significantly more data exist for lakes within the Atlantic Region. Alpha-BHC, gamma-BHC and PCB's were observed at some sites in the Region with alpha-BHC, Figure 2, being the most frequently observed. The majority of the observations are within twice the detection limit (<0.001 μg/L) but several basins stand out on Figure 2 with somewhat higher inter quartile ranges. Basins DC and DD which encompass the Annapolis Valley, reported single maximum values between 0.008 and 0.01 μg/L. The areas around Halifax, Port Hawkesbury and Sydney, Nova Scotia (basins EJ, FA and FJ) also had slightly higher median values. Surprisingly basin VC on the Quebec-Labrador border had the highest reported single observation for alpha-BHC of 0.028 μg/L, while two other remote Quebec-Labrador

basins, XB and XC, displayed median alpha-BHC values that were higher than those from lakes in proximity to the aforementioned industrial areas. Conversely, basins WB and XA also in Labrador were at detection limit values for alpha-BHC.

Gamma-BHC, Figure 3, was also observed for lake water in six basins; three, AF, AJ and AK along the Saint John River, CB on Prince Edward Island and VC and XC in Labrador. The United States Environmental Protection Agency (USEPA) has established a guideline for gamma-BHC for the protection of freshwater aquatic life of 0.01 µg/L (McNeely 1979) while CCREM (1987) recognize a guideline of 0.01 µg/L for total hexachlorocyclohexane isomers. A single observation (0.011 µg/L) in Basin DP of Nova Scotia exceeded this guideline while all the observations from Basin VC on the Quebec-Labrador border were in excess of this CCREM guideline. All gamma-BHC observations, Figure 3 were one to two orders of magnitude below the USEPA guideline for protection of freshwater aquatic life. Even though the levels of the two isomers of hexachlorocyclohexane were observed at low levels it does illustrate the concept of long range transport of air pollutants. Both alpha-BHC and gamma-BHC have been observed in precipitation from the region (Brun 1982, 1983, 1984).

Polychlorinated biphenyls, Figure 4, were observed in lakes in basins AF, AH, AJ and AK which are in the middle of upper reaches of the Saint John River, including its major tributaries. No PCB's were reported in any of the other basins or water types. There were only 17 water samples from harbours and they were all less than detection limit for total PCB. Both CCREM (1987) and McNeely (1979) have quoted guidelines for protection of freshwater aquatic life of 0.001 µg/L for polychlorinated biphenyls. This guideline however is below the detection limit of the technology used to obtain the results. Observations in basins AF, AH, and AK were clearly in excess of this limit. Five, four and five observations were used to generate the Box and Whisker diagrams for basins AF, AH and AK respectively. Some of the samples were collected at the

headponds of hydroelectric generating stations. Sediment values from the same basins support the observations as basins AF, AH and AK reported the highest maximum values in New Brunswick. Also freshwater biota from the Quebec-Labrador surveys indicated the presence of PCB's implying a water column component.

The principal organochlorine insecticide observed in bottom sediments was DDT and its metabolites. There were not enough bottom sediments observations reported from rivers and streams with which to plot Box and Whisker diagrams. There were, however, many more bottom sediments collected from lakes and the results for the sum of DDT (ΣDDT) and its metabolites is presented in Figure 5. Total DDT was observed in several lake samples with the highest observations coming from basins CB, DC, and DD representing Prince Edward Island and the Annapolis Valley of Nova Scotia. Basins in New Brunswick, AH, AJ and AK, along the Saint John and Tobique River Valleys also had slightly higher DDT totals. As these basins have been the principal centres of agriculture in the region it is not surprising that the highest levels of this persistent organochlorine have been observed in lake sediments. The remote areas of Quebec-Labrador, basins VC, XA, XB, and XC were, for the most part, less than detection limit and where there were positive results they were at or slightly above detection limit values.

Half of the PCB observations in lake bottom sediments (Figure 6) were below the detection limit of 0.005 mg/kg. All median values lay below 0.02 mg/kg for these basins sampled with the exception of basin ED, whose median observation was 0.022 mg/kg. This basin includes Kejimkujik and Rossignol Lakes. These higher levels at Kejimkujik and Rossignol lakes is attributed mostly to unidentified localized sources of PCB as an adjoining basin (EC) displayed no PCB in either medium nor did Kejimkujik and Rossignol display any observations of polyaromatic hydrocarbons which are usually indicative of associated anthropogenic inputs. PCB's were also detected in lake sediments in basin WB on the Quebec-Labrador border. All of the observations in basin WB were above the

detection limit with a median value of 0.012 mg/kg. Three other remote basins, XB, XC and VC were all reported as less than 0.005 mg/kg. Any observed PCB levels in Atlantic Region lake sediments are well below the levels that have been observed in the Great Lakes. Niagara River sediments were found to contain up to 2.7 mg/kg and western Lake Erie sediments ranged from 0.02 to 0.675 mg/kg. The low levels observed in the Atlantic Region in some relatively remote areas (Labrador) seems to suggest that localized point sources are the principal contributors. The maximum values observed in basins AF, AH and AK of New Brunswick support the higher levels that were observed in water from the headponds. The small sample size precludes any hypothesis as to the origin save to say that above Edmundston in basin AD, no PCB was observed in bottom sediments. The only sources could have been either industrial or municipal in nature.

As with other parameters, the highest bottom sediment observations for PCB have been recorded in the major harbours of the region. Both Port Hawkesbury, Nova Scotia and St. John's, Newfoundland reported median values in excess of 1 mg/kg, Figure 7. Three other basins, DP, YO and ZB, had median values in excess of 10 times the detection limit (0.005 mg/kg). No samples were available for Sydney Harbour which had the highest levels of other contaminants. These levels are lower than bottom sediment values reported for the Great Lakes (CCREM 87) which have a significantly greater population and industrial base.

Most of the biota samples quantitated for organochlorines and polychlorinated biphenyls originated from the Quebec-Labrador transboundary study. Muscle, liver and gonadal tissue were analysed for the persistent organochlorines and PCB's. Box and Whisker diagrams were not generated for biota as captured fish were dissected and quantitated. Lockerbie (1987) has reported in detail the magnitude of the Quebec-Labrador study and its observations. Polychlorinated biphenyl, alpha-BHC, gamma-BHC, and metabolites of DDT were observed in the dissected fish samples. Levels of

contaminants present in the edible portions of the captured fish were below Health and Welfare guidelines for human consumption (Lockerbie 1987). The highest reported concentrations were observed in liver tissue with the next highest in gonadal tissue. This pattern follows the percent lipid content of each type and represents the lipophilic nature of the organochlorines. The significance of these observations lies in that though the persistent organochlorines and PCB's were in most cases below detection limits in water and sediment, the fish residing in the sampled basins indicated that the contaminants had reached the basins at some point and time and were being biomagnified.

Though DDT has not been used since the early 1970's in Canada, it is still used in Third World nations to combat malaria carrying insects (NOAA 1987). The observations noted from 1980 onward indicate that DDT is still manifesting itself in the aquatic environment.

Other whole fish samples (seventy-three) taken during the same period along the Saint John River and in 1985 in Prince Edward Island also contained levels of organochlorines and in some cases PCB's. The PCB's were observed in fish taken from the Aroostook River and the Saint John River in October and November of 1983 with the highest reported level of 0.23 mg/kg of whole fish tissue and a minimum amount of 0.006 mg/kg.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons have been observed in surface water, precipitation and in bottom sediments throughout the Atlantic Region. Though some PAH's may be produced by natural processes such as volcanos and forest fires the majority of PAH's present in the environment are as a result of anthropogenic inputs (CCREM 1987). The combustion of fossil fuels is one of the major contributors of PAH as are several industrial processes such as petroleum refining, coal mining, steel manufacturing and the pulp

and paper industry. In addition, the aforementioned industries can contribute PAH's to the atmosphere where they can be transported and deposited in wet precipitation (CCREM, 1987). Polycyclic aromatic hydrocarbons are for the most part associated with any particulate matter present in the water column and are soon sorbed by any suspended or bottom sediments. This is especially true of the higher molecular weight PAH's (CCREM 1987).

From 1980 to 1987 the Water Quality Branch has collected and analyzed water, bottom sediment and biota for several of the PAH's. Those PAH's quantitated (Table 2) include: fluoranthene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno (1,2,3,c,d) pyrene, and benzo(g,h,i)perylene. Seven hundred and thirty-nine water samples, two hundred and fifty-eight sediment samples and twenty-nine biota samples were analyzed from the Atlantic Region. After data validation to eliminate quality control samples and those samples with improper station numbers, 680, 250, and 29 samples respectively, remained for interpretation.

The data obtained support the literature (CCREM 1987) in that fluoranthene, a relatively low molecular weight PAH, was the only one observed in surface waters of the region. Observed levels ranged from less than detection limit (<.001 μg/L) to a maximum of 0.12 μg/L. In stream and river waters, Figure 8, the majority of the observations lay between the detection limit, 0.001 μg/L, and 0.01 μg/L, with the exception of the CB sub-basin on Prince Edward Island, where the median value was 0.01 μg/L for fluoranthene. Water samples from lakes and ponds, Figure 9, however were somewhat different in that sub-basins AD, AF, AH, AK and AO in New Brunswick and FA on Cape Breton Island had maximum inter quartile range values in excess of 0.01 μg/L. These higher levels would be attributed partly to higher residence times in the lakes but more likely the industrial inputs of the pulp and paper industry along the Saint John River, fossil fuel activities associated with the New Brunswick Coal Mining Company at Minto in Basin AO, and industry in and around Port Hawkesbury, Nova Scotia. Aside from

known industrial sources, the levels present in the waters of the Atlantic Region fell between 0.001 µg/L and 0.012 µg/L indicating the ubiquitous nature of PAH contamination. The highest levels of fluoranthene in water were observed in samples taken from estuaries and harbours, Figure 10. Sydney, Nova Scotia, had the single highest observed level of 0.12 µg/L and a median of 0.09 µg/L followed closely by St. John's, Newfoundland with a median of 0.08 µg/L. These levels are not surprising given the levels present in sediment and the industrial/municipal inputs of each area. The other estuaries and harbours sampled all ranged from detection limit to 0.02 µg/L. No guidelines for freshwater aquatic life have been defined for the polyaromatic group. Benzo(a) pyrene has been shown to bioaccumulate in some lower organisms while some higher organisms can degrade it (CCREM 1987). Variable effects of PAH's on aquatic plants have also been observed (CCREM 1987).

As opposed to the surface water data all six quantitated PAH's were observed in bottom sediments. There were not enough bottom sediments collected from rivers and streams with which to plot sub-basin charts. However, 142 lake/ponds and 100 estuary/harbour samples were validated and plotted. Figures 11 to 16 display the individual PAH parameter boxplots for lake bottom sediments, while Figures 17 to 22 contain the corresponding data for estuaries and harbours. The median values for fluoranthene in bottom sediments from lakes, Figure 11, all lay below 0.20 mg/kg. The single highest value was 1.07 mg/kg in sub-basin AF which is in the Edmundston, New Brunswick area. Figure 17 illustrates that eleven of the estuaries and harbours sampled had median fluoranthene values below 0.10 mg/kg, seven lay between 0.10 and 1.00 mg/kg and three in excess of 1.00 mg/kg. As with the water samples, bottom sediments from Sydney Nova Scotia and St. John's had the highest median values for fluoranthene with 10 and 8 mg/kg respectively, Figure 17. The levels of PAH's present in the estuaries and harbours was of such a wide range that it necessitated the use of a log y axis when generating the Box and Whisker diagrams. A similar pattern for the other five PAH's was observed in that the majority

of the median values for lake sediment all fell below 0.10 mg/kg, and the harbours of Sydney and St. John's were the most contaminated.

Totals of the six PAH's quantitated were then plotted for the same basins, Figures 23 and 24, representing lakes and harbours respectively. The values generated may be biased low as only 6 PAH compounds were quantitated while the USEPA routinely quantitates 16 priority PAH's (NOAA, 1987). Figure 23 illustrates that with the exception of sub-basin AR, all lake bottom sediment median values for total PAH were below 0.4 mg/L. The higher values in AR are attributed to the past logging practices associated with the pulp and paper industry as well as anthropogenic inputs from a known cottage area. Figure 24 indicates that Sydney Harbour, Nova Scotia; St. John's Harbour, Newfoundland; St. Croix Estuary, New Brunswick; Port Aux Basques Harbour, Newfoundland; Miramichi Estuary, New Brunswick; and Saint John Harbour, New Brunswick, were the most contaminated by polycyclic aromatic hydrocarbons, in that order.

Sydney Harbour is a special case in that the levels of PAH's reported by the Water Quality Branch are in fact low compared to results obtained from an intensive survey carried out by the Environmental Protection Service. The SYSCO Steel mill is a known source of PAH contamination. The coking of coal is the major route of PAH's into the environment with coal tar distillates containing up to 48% PAH content (Matheson et al., 1983). As a result, the Sydney Steel tar pond contains up to 1% measured PAH to a depth of 1.5 m. Leaching of the tar pond has resulted in significant contamination of Sydney Harbour sediments and biota (Matheson et al. 1983). The initial phases of the Sydney Steel Tar Pond clean up have just recently commenced, with an estimate of a total cost of 34 million (Times and Transcript, 1987).

The levels of PAH present in Sydney Harbour are higher than any observations recorded by the United States National Oceanic and

Atmospheric Administration in their Marine National Status and Trends Program (NOAA 1987). They reported that the northeast had the highest levels of total PAH's in sediments and that Boston Harbour had levels of 26.4 mg/kg. The total of the 6 PAH's quantitated in Sydney Harbour range from 22.2 mg/kg to 73.9 mg/kg. The levels reported in St. John's, Newfoundland are comparable to the levels reported by NOAA in Salem Harbour, Massachusetts and Casco Bay, Maine.

The high levels of PAH in the sediments of the St. Croix estuary are somewhat surprising in that the St. Croix does not have the levels of population and industry that St. John's, Newfoundland and Saint John, New Brunswick have. There is a pulp and paper plant approximately 20 km upstream from the sample site. The observations were based on a triplicate sample which may have been affected by spatial variability. However, Figure 23 illustrates that lake bottom sediment from basin AR also had the highest median value for total PAH. That sampling site was located at Spednic Lake, which had been subject to logging activities in the past and current cottage activity. The Port aux Basques, Newfoundland, levels are most likely due to the activities associated with a marine port as it is the terminal for the principal ferry link with the mainland. The Miramichi estuary was sampled at Newcastle and the observation noted there would again be due partly to the pulp and paper industry but also shipping and a petroleum cargo terminal. Saint John Harbour and Halifax Harbour follow closely with the observations being attributed to the industrial base and the shipping aspects of each port. Both Halifax and Saint John have oil refineries in their harbour areas. The levels reported in the harbours represent point data and are not totally representative of the harbours sampled, but do serve to illustrate that the harbours of the region are the most contaminated sites.

The presence of PAH's in fish was not detected due most likely to the fish's ability to metabolize and depurate the compounds (CCREM 1987). Only 29 fish were analyzed and none came from the

high level estuaries/harbours previously mentioned.

As PAH's may enter the aquatic environment from several industrial sources it is not surprising to find the reported levels in harbours due to the amount of industry and shipping associated with Atlantic ports. The observed levels are a direct result of anthropogenic inputs. Though no limits exist for PAH's in the aquatic environment, the International Joint Commission has recommended that a level of 1 mg/kg for sediments that serve as a food source for freshwater fish should not be exceeded (CCREM 1987). The salt water harbours of Sydney and St. John's both exceed the recommended level with median observations for fluoranthene alone of 10 and 8 mg/kg respectively.

Phthalic Acid Esters (PAE's)

Phthalic Acid Esters are a significant group of industrial chemicals which are used as plasticizers in the manufacture of plastics, cosmetics, inks, insect repellants and other products (Leah 1977). Sources of phthalates in the environment are PVC manufacturing plants, textile and paper industries, landfills and incinerators (CCREM 1987).

The Water Quality Branch data with respect to PAE's in the Atlantic Region is limited to water representing 11 sub-basin stream sites and 9 estuary/harbour sub-basin sites. With the exception of stream samples from basin CB on Prince Edward Island all basin data plotted on the Box and Whisker diagrams represent three observations. The diagrams present the total PAE's present and is based upon the analysis of dimethyl phthalate, diethyl phthalate, dibutyl phthalate, diethylhexyl phthalate, dipropyl phthalate and dioctyl phthalate.

Maximum observed values for total PAE were similar in both stream and harbour water, Figures 25 and 26, with St. John's harbour recording the highest observation of 20.7 μg/L followed by

Saint John with a maximum of 18.4 µg/L. Leah (1977) felt that there was "considerable uncertainty" as to whether phthalate observations in samples is naturally occurring or represents partial contamination from the sampling, handling and laboratory processes. Pierce et al. (1980) also express concerns about contamination of environmental samples. Nevertheless, the observed levels are of the same order of magnitude as those observed in surface waters of the St. Clair river in Ontario (CCREM 1987).

As with other chemical grcups, the highest levels observed have been in the harbours and in close proximity to industrialized areas. There is limited information with respect to cycling of phthalate acid esters in the aquatic environment making it difficult to ascertain the significance of metabolism (Pierce 1980). Several authors have reported phthalate metabolism by bacteria, invertebrates and fish species (CCREM 1987).

Triazine Herbicides

The triazine herbicides are used extensively in Canada as pre and post emergent herbicides used to control broad leaf and grass weeds. Three triazines, Table 3, have been quantitated by the Branch: atrazine, simazine and metribuzine. Because of the agricultural use of these compounds, monitoring programs have been centered in areas under cultivation where one or more of the herbicides was in use. Of the three, the greatest amount of data exists for atrazine, (128 observations).

Figure 27 illustates that atrazine has been observed in streams in three sub-basins in the region: CB on Prince Edward Island, DC and DD in Nova Scotia. Atrazine has also been observed in ponds and lakes as illustrated by Figure 28 where 3 sub-basins have reported atrazine; AF in New Brunswick, CB on Prince Edward Island, and DC in Nova Scotia. In all cases the observations were recorded in areas of extensive agriculture where atrazine was used. The levels reported are within the ranges observed in some streams

in Southern Ontario and Quebec.

The triazines are environmentally significant in that they have been reported as leaching into ground water in other areas of North America (Gillis et al. 1986) and as a result atrazine has been given high priority as a ground water pollutant.

Simazine and metribuzine were not reported in water samples from the areas studied. Metribuzine is used in the potato industry and because of the leaching characteristics of the triazine group is also a priority of the Water Quality Branch in its ongoing agricultural use studies.

Less Frequently Observed Parameters

While the five previous chemical groups have been frequently reported in the region there are several chemical groups wherein the majority of the observations have been reported as "less than detection limit". This group includes: carbamate pesticides, chlorophenols, chlorobenzenes, chlorophenoxy acids, tri-aryl-phosphates, and organophosphorus pesticides. The relatively few positive observations precludes the drawing of Box and Whisker diagrams but their inclusion in this assessment was important as they illustrated the number of analyses performed by the Water Quality Branch, the extent of the data base, and included several in-use biocides.

Carbamate Pesticides

The carbamate group is quite broad with several compounds being used in Canada as insecticides, fungicides, and herbicides. As a group they are less persistent than the organochlorines and have displayed insecticidal selectivity (CCREM 1987). The principal carbamates investigated by the Branch are listed in Table 4. Three hundred and seventy surface water samples have been quantitated for two principal carbamates: carbaryl and carbofuran.

Both of these products have been used extensively in agriculture in the region. One observation for carbaryl in Silver Lake, Nova Scotia, was reported at a level of 0.10 µg/L which was 10 times the detection limit while carbofuran was observed at 5 sites in the Saint John River and one site at Washademoak Lake at levels of 0.06 µg/L which was 2.5 times the detection limit. The carbofuran observations were recorded at the Pokiok and Mactaquac Headpond reaches of the Saint John River. Carbaryl and carbofuran are broken down primarily through alkaline hydrolosis, photolysis and biodegradation. Significant bioaccumulation is not expected because of the limited lipophilic nature of the group (CCREM 1987).

Two hundred and forty-two surface water samples have been quantitated for aldicarb and its two metabolites, aldicarb sulfone and aldicarb sulfoxide. Due to changing methodologies detection limits have varied considerably ranging from 3.0 µg/L to 0.01 µg/L. Only one observation for aldicarb was reported in surface water in basin BO of New Brunswick.

No carbofuran was observed in bottom sediments, and no biota samples were collected for carbofuran analysis.

Carbamates have been investigated by the Water Quality Branch in ground water samples from Prince Edward Island. Samples have been quantitated for carbaryl, carbofuran, aldicarb, aldicarb sulfone and aldicarb sulfoxide with aldicarb and its degradation products having been observed. This is due to the high solubility of aldicarb and its extensive use on P.E.I. in the potato industry. Ecobichon et al. (1985) and Gillis et al. (1986) report the presence of aldicarb in groundwater from New Brunswick and Prince Edward Island respectively.

Chlorophenols

Chlorinated phenols, Table 5, are another group of chemicals that have been used in industry in Canada. Pentachlorophenol and

tetrachlorophenol have been used as wood preservatives, bactericides, and fungicides in the paint, leather and fabric industries (CCREM, 1987). Not all of the isomers have been used in industry. The presence of chlorophenols in the environment has been associated with: industrial effluents of pulp and paper operations and wood treatment facilities, the chlorination of sewage treatment effluent and the treatment (chlorination) of municipal water supplies (CCREM, 1987).

The Water Quality Branch has investigated the presence of chlorophenols in the waters of the Atlantic Region. In total 366 water samples have been quantitated for one or all of the chlorophenols listed in Table 5. The majority of these samples are a result of the municipal drinking water sources toxic chemical survey and represent raw sources of drinking water.

WQB analytical results have shown that the majority of the observations are less than the method detection limits used for quantitation and, where positive values have been recorded, they have been attributed to sampling in proximity to wooden structures that may have been treated with pentachlorophenol. This does not imply that chlorinated phenols are not a concern in the Atlantic Region, but reflects a sampling bias created by a program designed to assess a specific water use sector. CCREM (1987) tabulated concentrations of chlorophenols in industrial effluents and lagoons in New Brunswick and Nova Scotia in 1980 associated with 12 industries. Observations are cited for 2,4-dichlorophenol, 2,4,6-trichlorophenol, 2,3,4,6-tetrachlorophenol and penta-chlorophenol.

No bottom sediment or biota samples were collected by the Water Quality Branch for chlorinated phenol analysis.

Chlorinated Benzenes

Chlorinated benzenes, Table 6, are a class of chemicals used in industrial processes. Some are used as solvents, pesticides, dielectric fluids, deodorants and chemical intermediates (CCREM, 1987). Eleven chlorobenzenes, Table 6, have been quantitated by the Water Quality Branch in the Atlantic Region representing 631 water, and 118 bottom sediment samples. As with the chlorinated phenols, the majority of the analytical results were below the detection limits established for the methods with only a few samples reporting an observation above detection limits. Several samples had been reported as containing 1,4-dichlorobenzene which as it turned out was a facility contamination due to background interference identified as deodorant blocks.

The lack of positive observations does not imply that there is no impact from chlorobenzenes but reflects the monitoring programs under which the samples were collected. Hexachlorobenzene is a problem in the Great lakes - St. Lawrence system due to the number of chlorine plants on both sides of the border, and has been reported in the Niagara River as a result of leaching from toxic chemical dumps (CCREM, 1987).

Chlorophenoxy Acids

Chlorophenoxy acids, Table 7, and their derivatives have been extensively used as herbicides to control broad leaf plants and have been used along highway and railway rights of way to control vegetation. Part of the concern with the chlorophenoxy acid herbicides has been the presence of impurities in the technical formulations. TCDD (2,3,7,8-tetrachlorodibenz-p-dioxin), is one impurity that has been reported in 2,4,5-T, and is known to be teratogenic and very toxic (Stoker *et al*. 1976). In the Atlantic Region 2,4-D (2,4-dichlorophenoxyacetic acid) has been used extensively in Prince Edward Island, Nova Scotia and New Brunswick,

and has been assigned a priority two status on the Federal-Provincial list (Gillis et al. 1986).

Between 1982 and 1986 the Water Quality Branch conducted toxic chemical surveys of which the quantitation of 2,4-D and 2,4,5-T were components. These surveys were centered primarily in agricultural areas where the use of phenoxyacid herbicides was documented or suspect. One hundred and four water samples were quantitated for one or both of the aforementioned herbicides. Only three positive observations were noted: two observations of 2,4-D in the Annapolis River in Nova Scotia and one observation for 2,4,5-T in the Saint John River at the Grand Falls headpond. The 2,4-D observations were two orders of magnitude below the 4.0 µg/L guideline for freshwater aquatic life (CCREM 1987). The levels reported are similar to those observed in the Pacific and Central regions of Canada but lower than those levels reported in the Western Region. During the same 1982 to 1986 time period three hundred and two bottom sediment samples were collected and quantitated for the presence of 2,4-D and 2,4,5-T. Neither of the herbicides was observed in the bottom sediments at detection limits of 0.004 mg/kg and 0.002 mg/kg respectively.

Farm ponds and wells could be of potential concern as investigations in Ontario of suspected contamination indicated that 48% of the ponds and 60% of the wells had in fact been contaminated (CCREM 1987). Though Water Quality Branch data seem to indicate limited presence of 2,4-D and 2,4,5-T in the surface waters of the Atlantic Region, the potential for ground water contamination is real based on the amount of agriculture in the region.

Tri-aryl-phosphates

Tri-aryl-phosphates (TAP), Table 8, are a group of chemicals used by industry as fire retardants, lubricants, and plasticisers. Their presence in the environment was investigated in 1980 when 140 samples were collected and quantitated. Two TAP's were analyzed by

the Water Quality Branch: triphenyl phosphate, and tri-o-tolyl phosphate.

Only two sites in the Region had reportable levels of triphenyl phosphate: the Shubenacadie River at Elmsdale, Nova Scotia and St. John's Harbour, Newfoundland with reported levels 10 and 100 times the detection limit, 0.003 µg/L, respectively.

Bailey et al. (1983) expressed concern over the TAPs due to their widespread usage and importation into Canada. They also reported that there were mammalian effects to TAP exposure but very little was known about toxicity to aquatic organisms. No guidelines have been recommended for water, human consumption, or protection of the aquatic environment.

Organophosphorus Pesticides

The organophosphorus (OP) group of pesticides came into prominence during the 1950s and 1960s partly in response to the environmental impacts associated with the organochlorines and also as a result of developing insect resistance to DDT (Stoker 1976). Their most important property is their relatively short life in the environment combined with toxicities that are in some cases higher than the organochlorines. This high toxicity does pose a threat to non-target organisms (Pyle 1974).

Several organophosphorus compounds, Table 9, have been investigated by the Water Quality Branch from 1980 to 1987, Table 9. Four hundred and seventy water samples have been quantitated representing three project areas: the New Brunswick spruce budworm abatement program, basin specific toxic chemical surveys, and the municipal drinking water sources survey. Spruce budworm spray monitoring spanned the period of the late 1970s to 1983. The 1980 to 1983 aspects of Water Quality Branch involvement was in the monitoring of off-target drift onto Federal lands. Precipitation collectors and XAD-resin columns were used to quantitate

fenitrothion and the carbamate, aminocarb. Analytical results indicated that during all three sampling seasons atmospheric drift and presence of fenitrothion in rainfall occurred (O'Neill et al. 1987). No aminocarb was observed in the collectors from 1980 to 1983. The implication from these observations is that fenitrothion was being inputed into the aquatic environment via precipitation. Fenitrothion has been observed in surface water throughout New Brunswick. The presence of fenitrothion has been indicated in: the Saint John River at Grand Falls and Gagetown, the Nepisiquit River, the Southwest and Northwest Miramichi Rivers, and in the estuaries of the Restigouche, Nepisiquit and Miramichi Rivers. The highest reported observation was 0.13 μg/L reported for Bathurst Harbour in the estuary of the Nepisiquit River. Of the other positive observations (19 in total), 7 were an order of magnitude lower and, 12 were two orders of magnitude lower than the Nepisiquit observation. Terrestrial effects of fenitrothion applications have been reported by Busby et al. (1984).

Several other organophosphorus pesticides have been observed in surface waters in the region. Guthion, phorate, ethion, and trithion have all been observed on an infrequent basis at levels at or slightly above detection limits. These observations have been reported as a result of the municipal drinking water sources study. No pesticide exceeded the Health and Welfare (1978) guidelines for the specific pesticide. Many of the obsevations were noted in only 1 sample of a duplicate or was not observed in a subsequent sampling. These very low levels do however indicate the susceptibility of watersheds to contamination.

Also of concern are 5 individual observations of one of the aforementioned OPs in groundwater from New Brunswick and Prince Edward Island. These levels were also at detection limit and their single instance basis indicates an emerging area of concern.

CONCLUSIONS

The aquatic environment of Atlantic Canada has been exposed to several toxic organic chemicals as a result of man's previous and current activities. Observations have been reported in water, bottom sediment and biota.

It has been shown that several ubiquitous compounds are present in the surface waters of the Atlantic Region. The polyaromatic hydrocarbon, fluoranthene, and alpha-BHC, a non-insecticidal isomer of hexachlorocyclohexane, have been observed in stream, lake, estuarine and harbour waters. Alpha-BHC and gamma-BHC have also been observed in remote areas of the Quebec-Labrador border and in precipitation. The persistent organochlorine DDT and its metabolites has been observed in sediments and biota in the region indicating that DDT entities are still undergoing biological cycling in the ecosystem.

Bottom sediments in the region have also been shown to contain levels of polyaromatic hydrocarbons that are due primarily to anthropogenic inputs. The highest levels of polyaromatic hydrocarbons, and polychlorinated biphenyls in sediments have been observed in the harbours of the region with Sydney, Nova Scotia and St. John's, Newfoundland in excess of other Atlantic ports.

In-use pesticides have been observed in areas where their presence can be attributed to agricultural activity. Atrazine, carbofuran, carbaryl, 2,4-D, 2,4,5-T, have been observed in surface water in the region, and aldicarb has been observed in groundwater in New Brunswick and Prince Edward Island in potato growing areas. Low levels of several organophosphorus insecticides in water have been reported as well.

Areas of industrialization; Halifax-Dartmouth, Port Hawkesbury, Sydney, Saint John, St. John's, Port aux Basques, have all shown levels of contaminants, especially PAHs, that are higher

than those levels observed in more remote areas. Fish tissue from Quebec-Labrador contained the metabolites of DDT and polychlorinated biphenyls implying a combination of past wide spread use and atmospheric transport.

Water Quality Branch data has illustrated atmospheric drift associated with the forestry application of aminocarb and fenitrothion in the New Brunswick spruce budworm abatement program.

As data were generated from different programs ranging from specific pesticide surveys and general screening surveys to municipal drinking water source surveys, so have the observed levels differed. The majority of the observations have been very close to detection limits indicating that contaminant levels are lower than those that have been observed in other areas of Canada and also reflects a certain program bias. The low frequency and levels of most observations does not imply that there is no potential for contamination of the aquatic environment, for there is. Where there is industry, agriculture, silviculture, landfills, and human activity, there exists the potential for impact to the environment.

The surface water component of the ecosystem is only a small aspect of the hydrological cycle. Groundwater, precipitation, particulates, sediment and biota are all inter-related and an input to one component may be manifested by an effect in another.

The obvious implications are to prevent further exposure and to minimize the possibility of the degradation of a vital resource. Preventative actions can only be realized through the co-operation of all levels of government, industry and the population at large.

RECOMMENDATIONS

As a result of this broad scope data review of Water Quality Branch toxic organic chemical data, there are several follow-up project areas that have been identified. Some of these are of ongoing concern and investigation by the Water Quality Branch, some may be of interest to other agencies to explore, and others may alleviate apparent data gaps.

The presence of agricultural biocides in the aquatic environment is, and should remain, a priority issue within the Water Quality Branch. As of January 1, 1985, there were 514 chemical pesticides registered for use in Canada (Eaton et al. 1986). Data generated by the Branch is useful in the post registration evaluation of an active agent and is beneficial to other federal and provincial agencies concerned with the persistence, fate and effects of chemical pesticides.

The relatively high levels of polyaromatic hydrocarbons in sediment from the St. Croix estuary could also be of interest to the Water Quality Branch as a complementary project to the ongoing St. Croix River monitoring project. The sources and magnitude of contamination could be explored to determine if there is potential impact on the reintroduction of fish stocks.

Other project areas of interest that would encompass further investigation are: an explanation of the observed levels of alpha-BHC and gamma-BHC in remote lake water along the Quebec-Labrador border that are in excess of observations from lakes adjacent to industrialized centres; a follow up of the high levels of PCB observed in headpond waters along the upper reaches of the Saint John River; and an attempt to identify the local sources for the observed PCB levels recorded at Kejimkujik and Rossignol Lakes in Nova Scotia.

Data gaps exist with respect to both parameter and site specific information. The majority of the data for chlorophenols and chlorobenzenes is as a result of the Municipal Drinking Water Supply Toxic Chemical Survey and the watersheds sampled tend to bias the data. Though municipal water supplies represent surface water habitats frequented by fish and wildlife, they tend to represent a more pristine type of water column. Information should be obtained from areas such as estuaries and near industrial/municipal sources in order to define if, and at what levels chlorphenols and chlorobenzenes are entering the environment. The A Basins in New Brunswick, all of P.E.I., and most of Nova Scotia have been surveyed in the past seven years, leaving data gaps in most of the B Basins in New Brunswick, DJ to DN Basins in Nova Scotia, the Great Peninsula of Newfoundland and all of Labrador excluding the basins along the 52nd parallel.

Because surface waters are in a continuous state of flux the monitoring of that component is subject to spatial and temporal variability. Water data represents only the time and place of collection. Because of the relationship of bottom sediment and biota to the water column, the use of these components is valuable as intergrators of the changing water column. The physical properties of a chemical will dictate what environmental component is most valuable as an indicator of presence.

The value of generating water quality data lies in the ability to record historical anthropogenic activity and inputs, current in-use practices and anticipating future problem areas. Therefore, the current practice of site and contaminant specific surveys should be continued, not only to deal with specific high priority issues of today but also to generate background information that would be useful in long term perspectives. Groundwater data indicates that there is an emerging problem of pesticides and environmental contaminants in the aquifers of the Atlantic Region. Project managers should be cognizant of past activities and

practices when allocating analytical resources in order to incorporate both long and short term objectives.

The continuation of inter-departmental and inter-governmental co-operation is also highly recommended for the inherent values of increased scientific authority, project scope, and cost effectiveness.

The long range direction, to minimizing any future environmental degradation, lies with the implementation of water resource management strategies that would encompass all components of the aquatic ecosystem.

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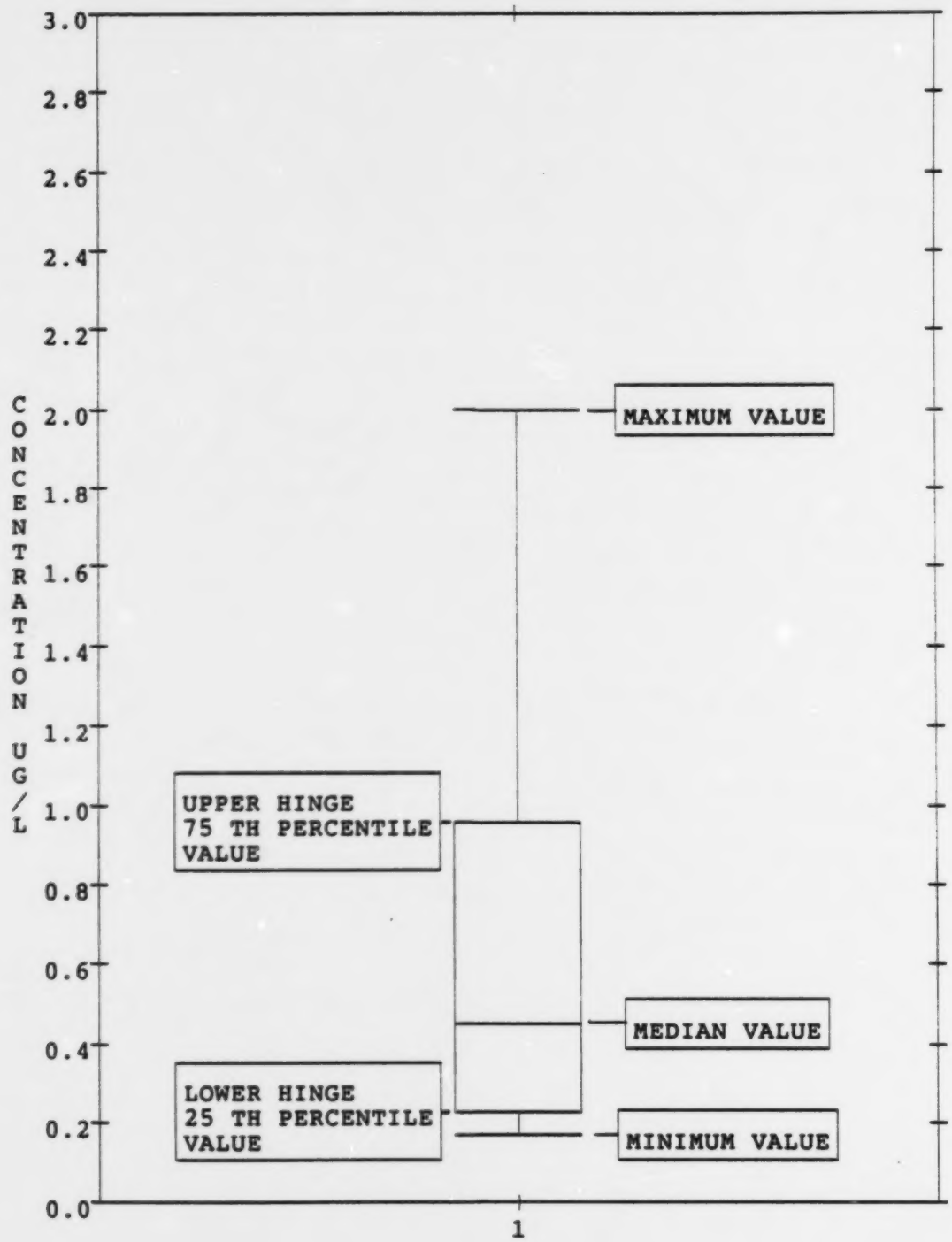
FIGURE 1A: BOX AND WHISKER PLOT DESCRIPTION



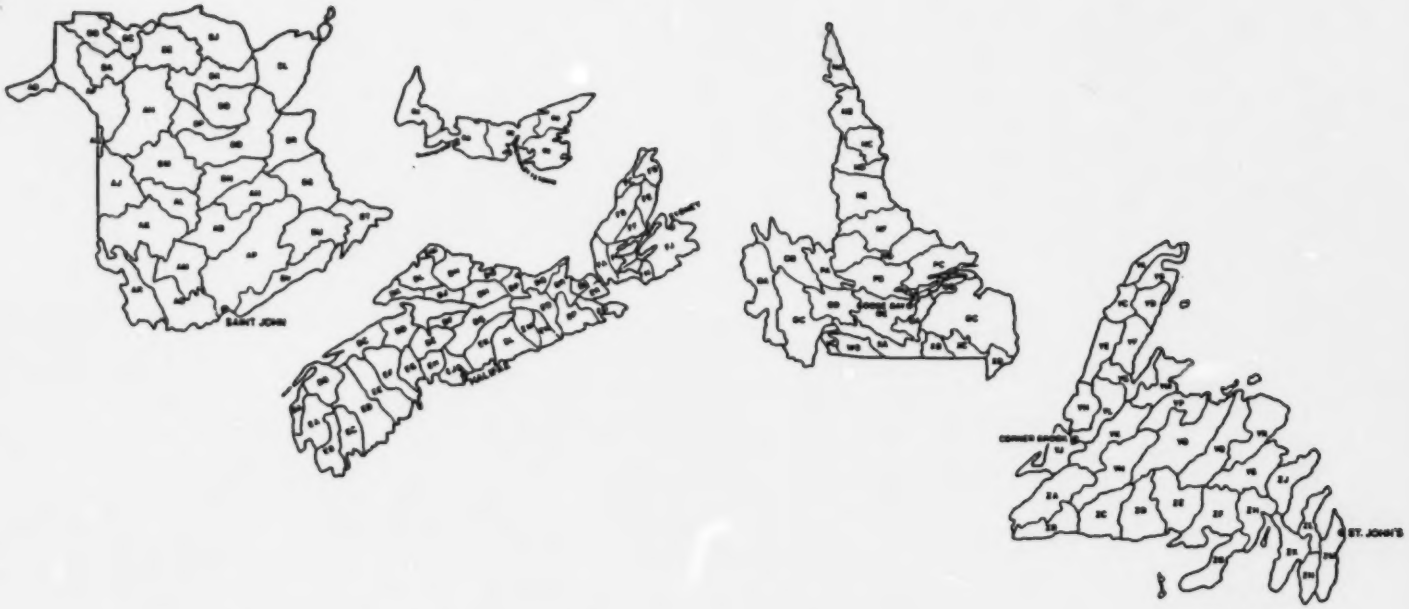
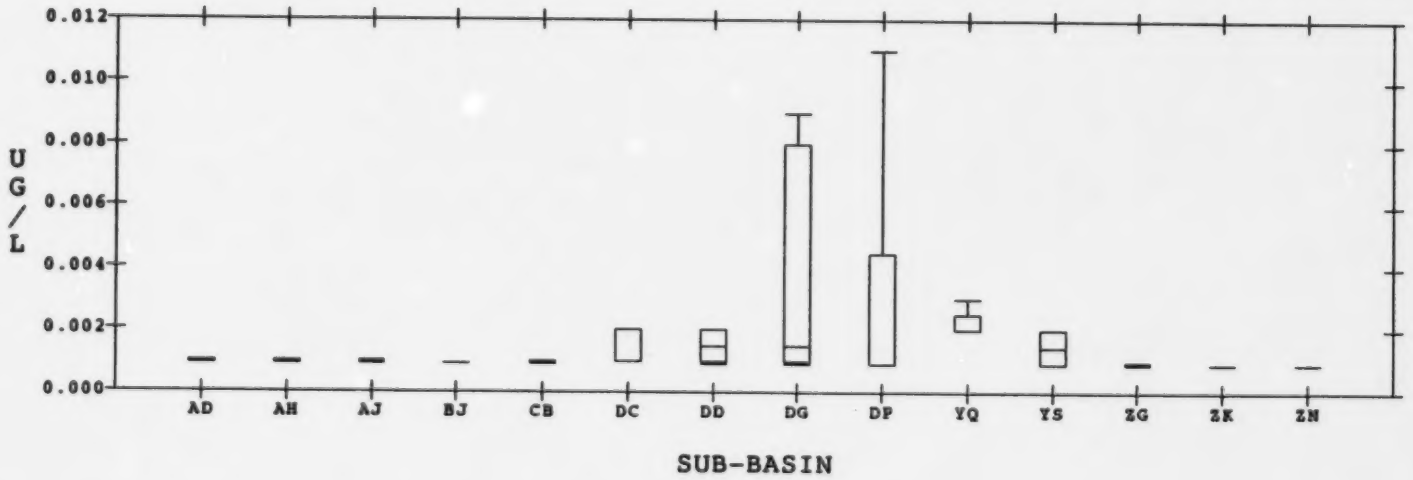


FIGURE 1: ALPHA-BHC IN RIVER WATER, REPORTED IN UG/L



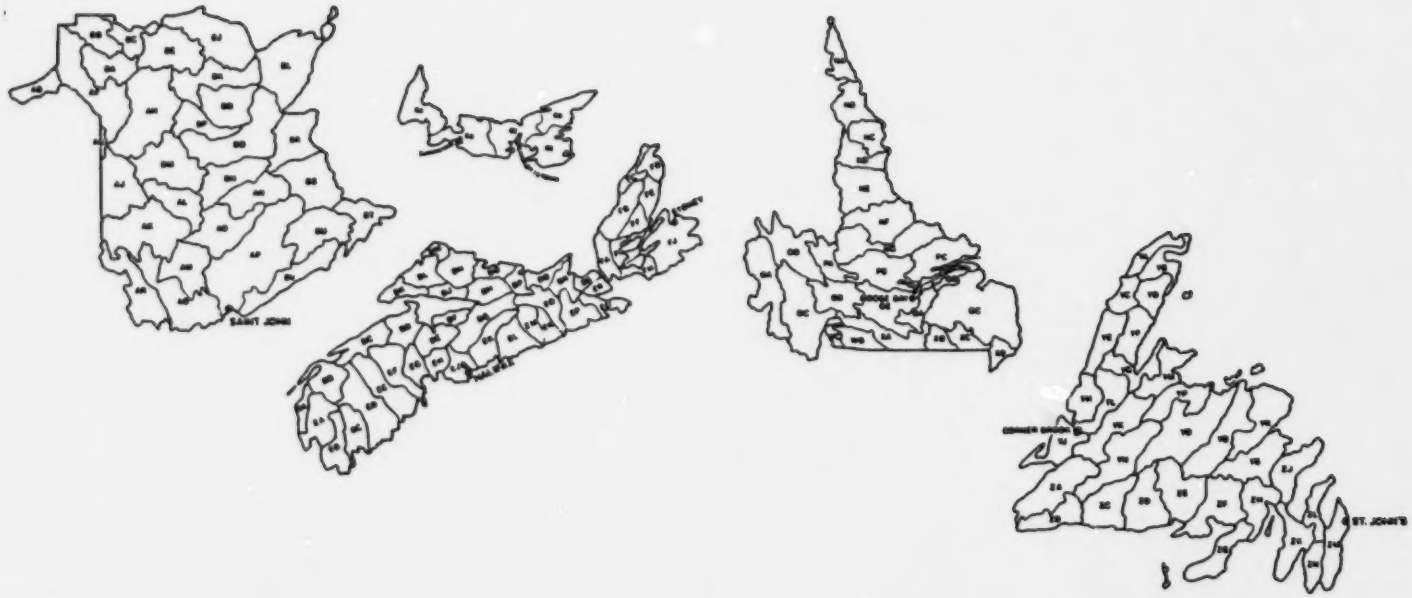
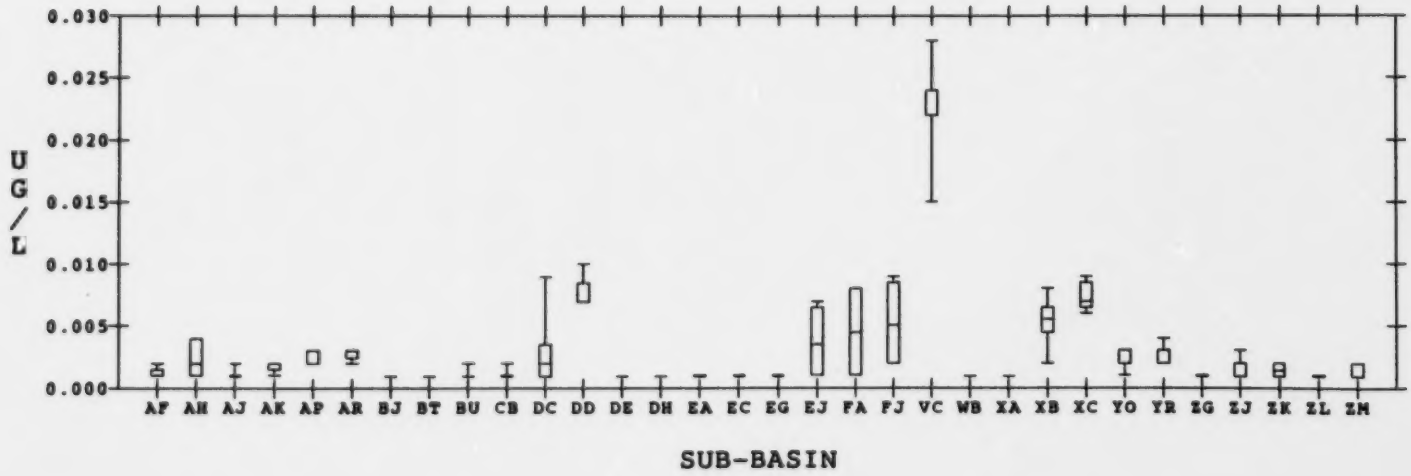


FIGURE 2: ALPHA-BHC IN LAKE WATER, REPORTED IN UG/L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0.025
0.020
0.015
0.010
0.005
0.000
UG/L
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SUB-BASIN

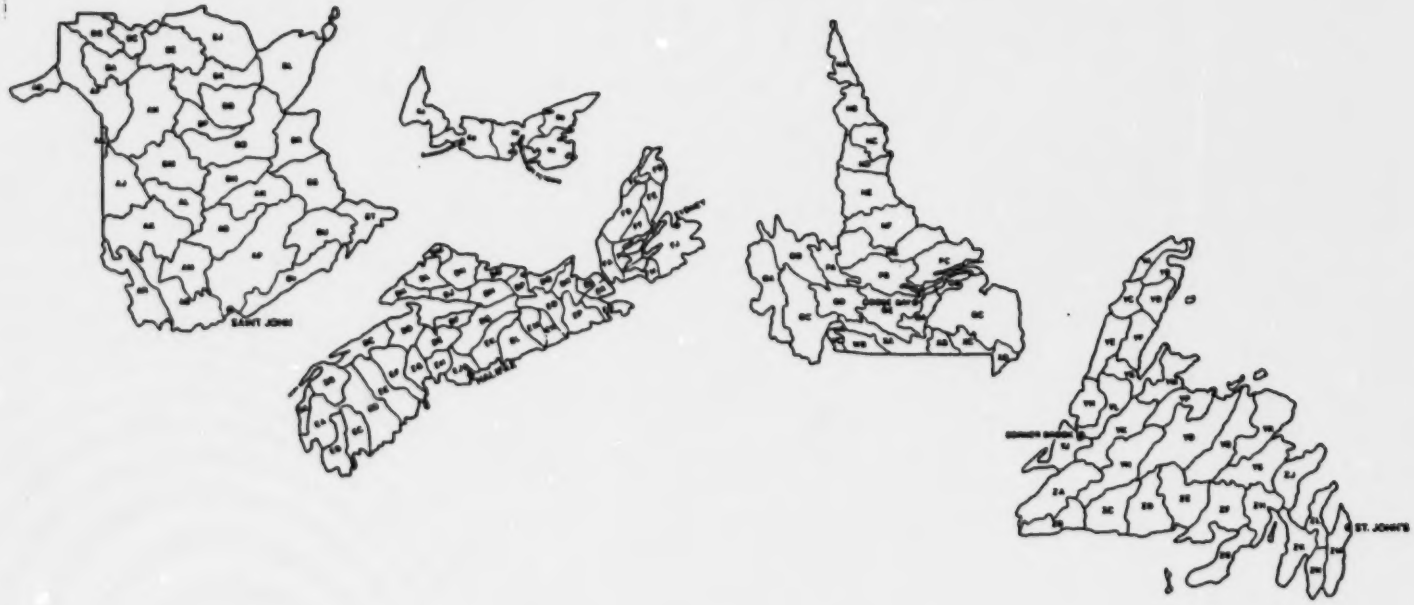
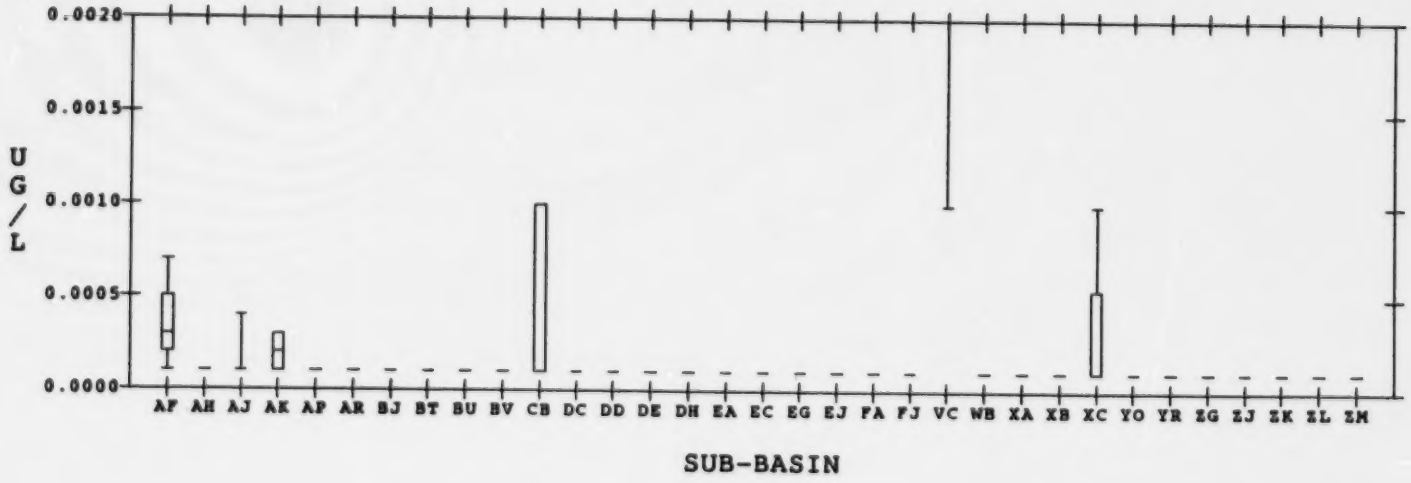


FIGURE 3: GAMMA-BHC IN LAKE WATER, REPORTED IN UG/L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SUB-BASIN

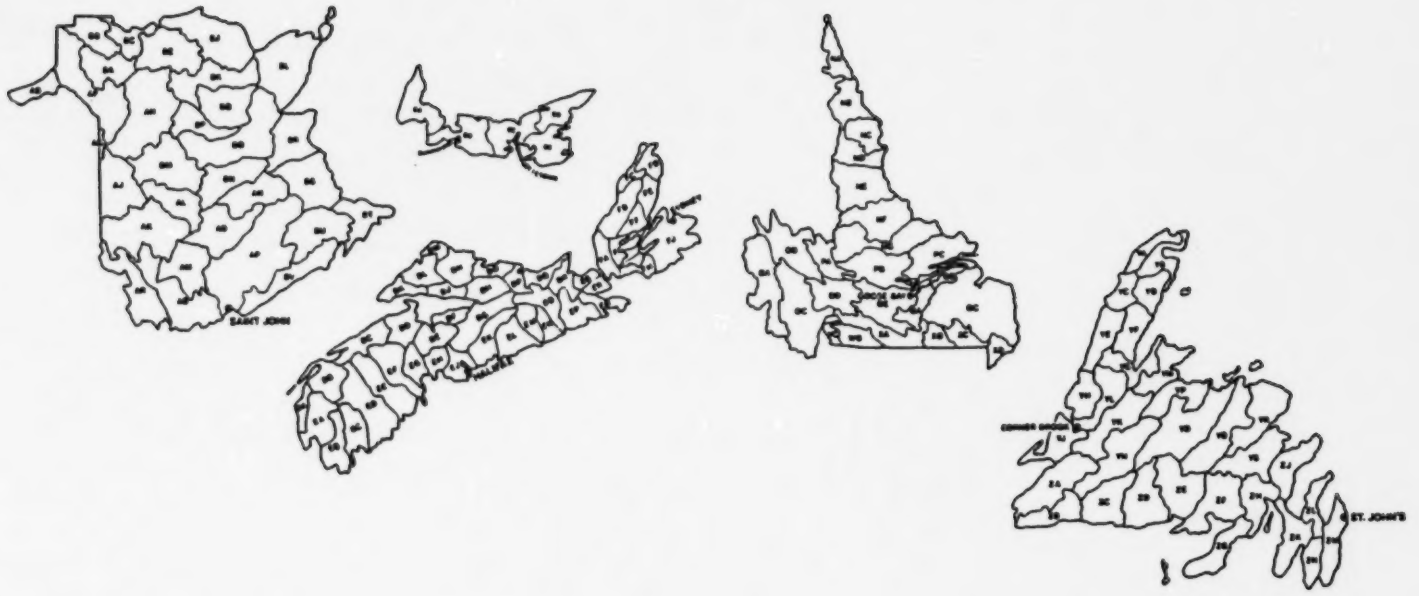
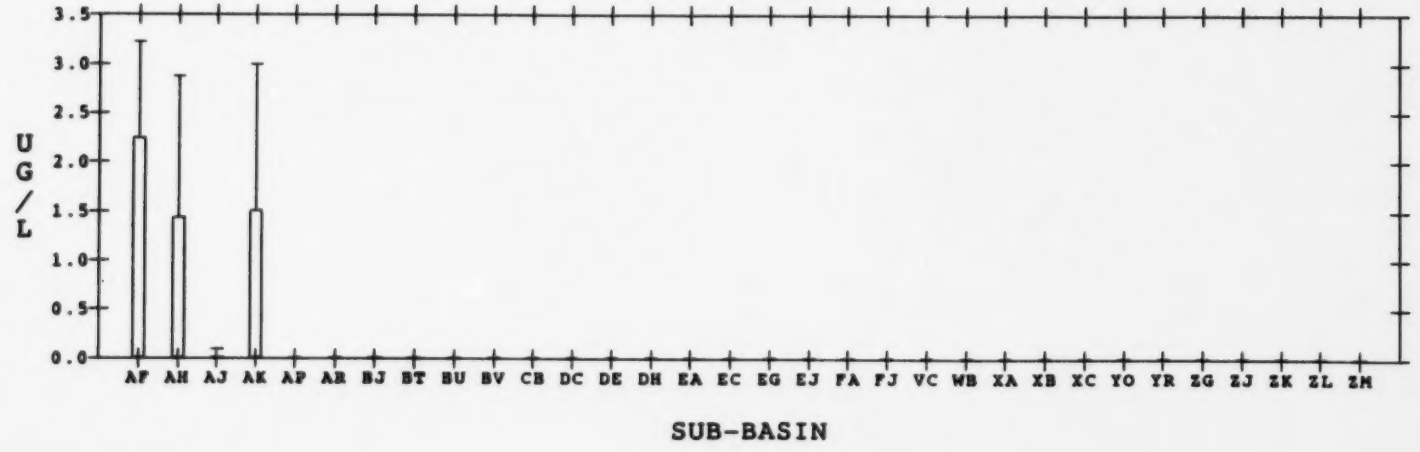


FIGURE 4: POLYCHLORINATED BIPHENYLS IN LAKE WATER
REPORTED IN UG/L



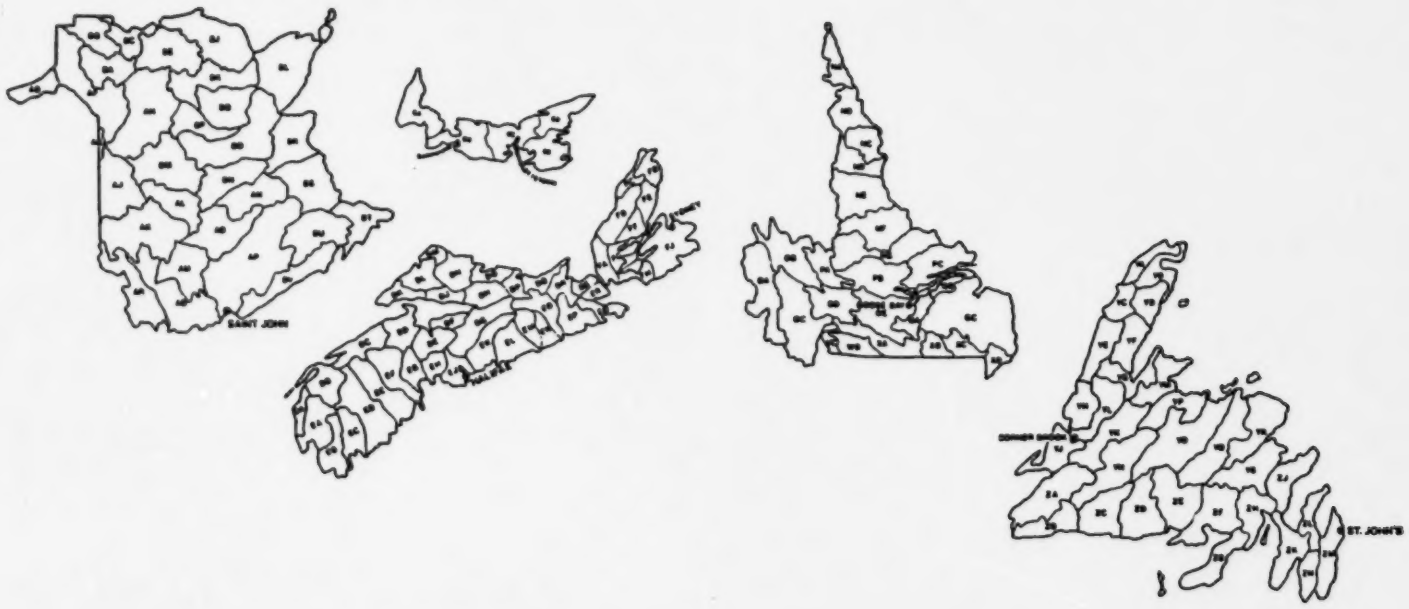
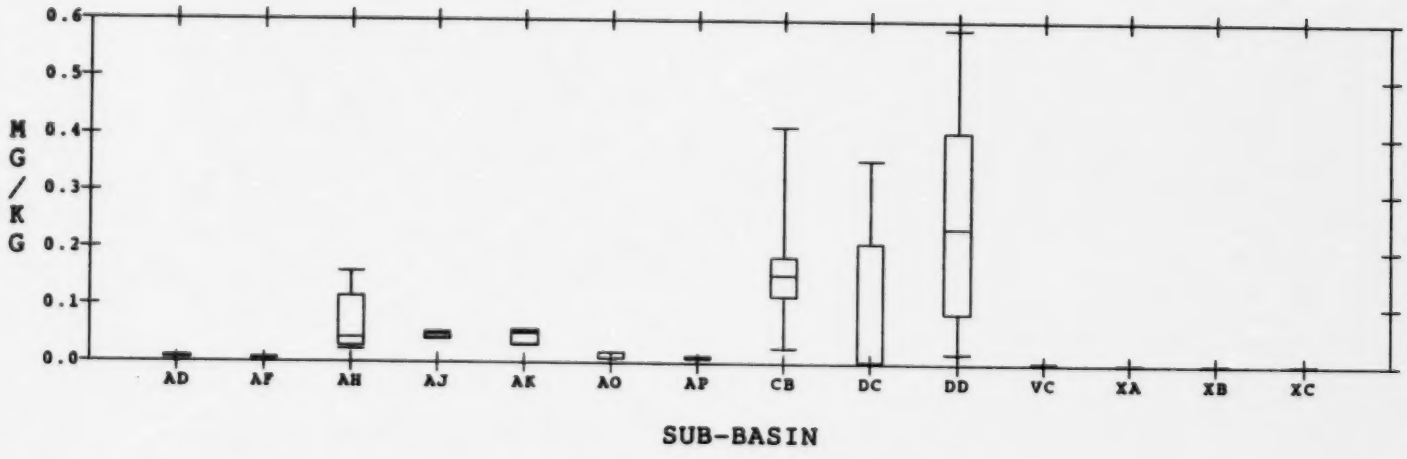


FIGURE 5: TOTAL DDT SUBSTRATES IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



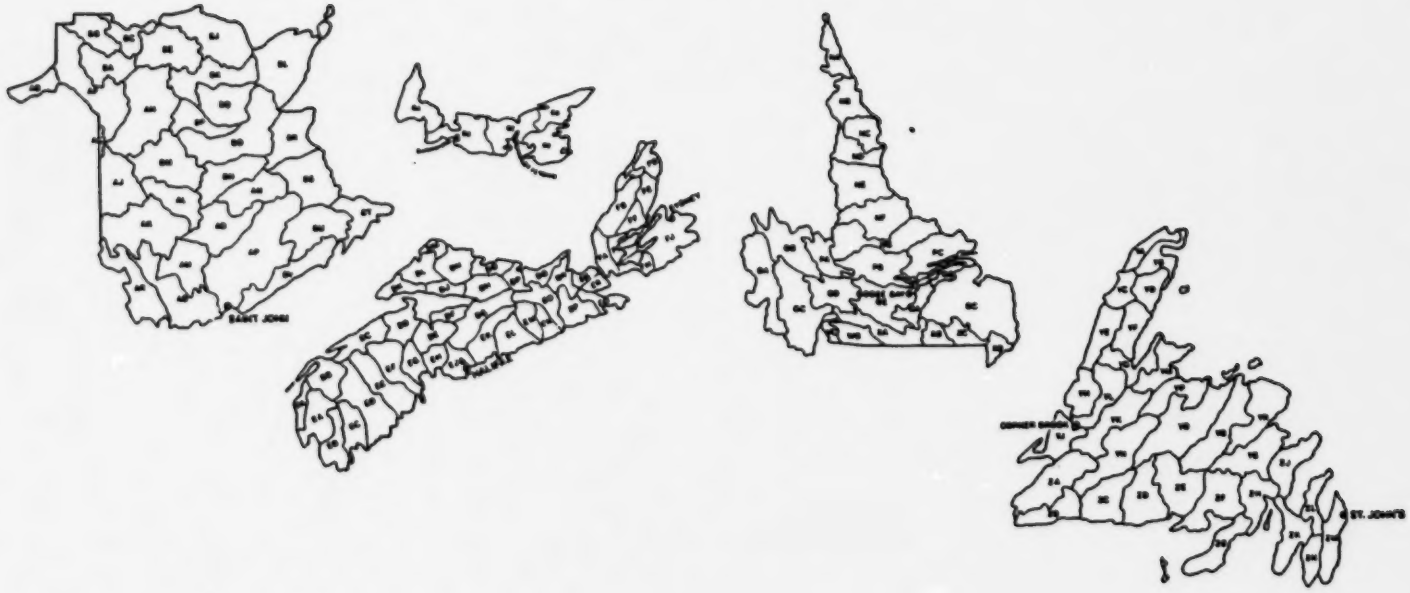
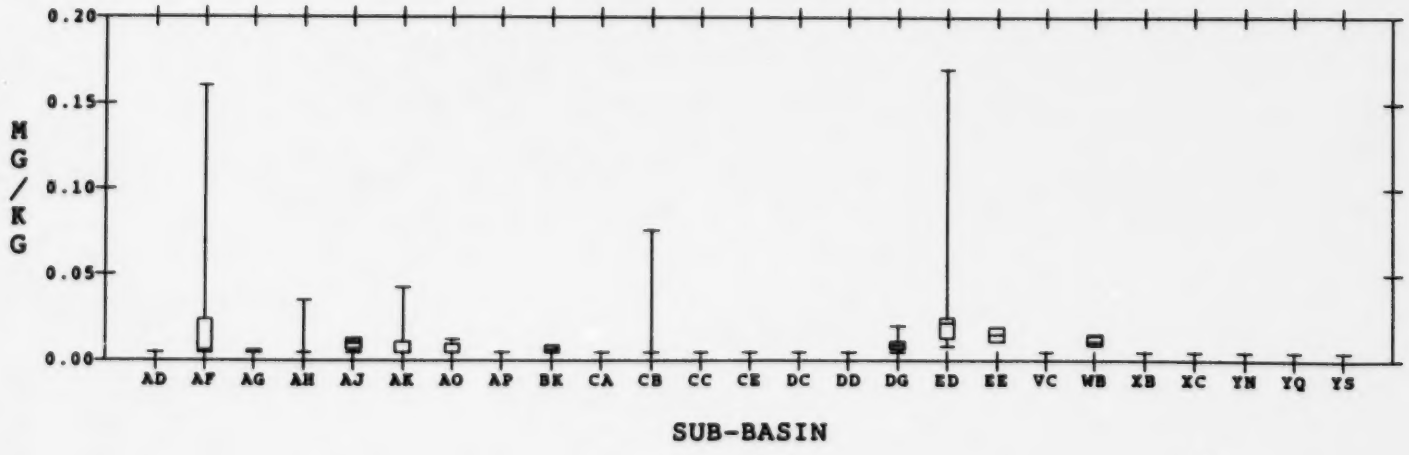


FIGURE 6: POLYCHLORINATED BIPHENYLS IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



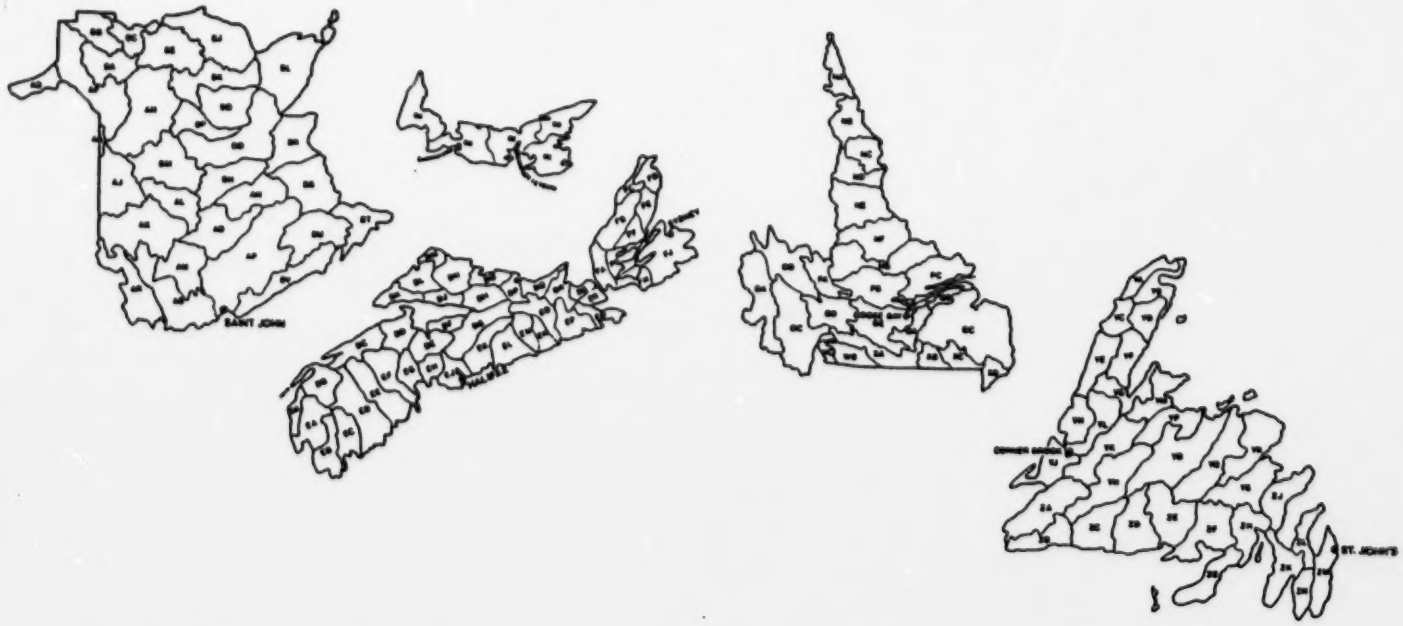
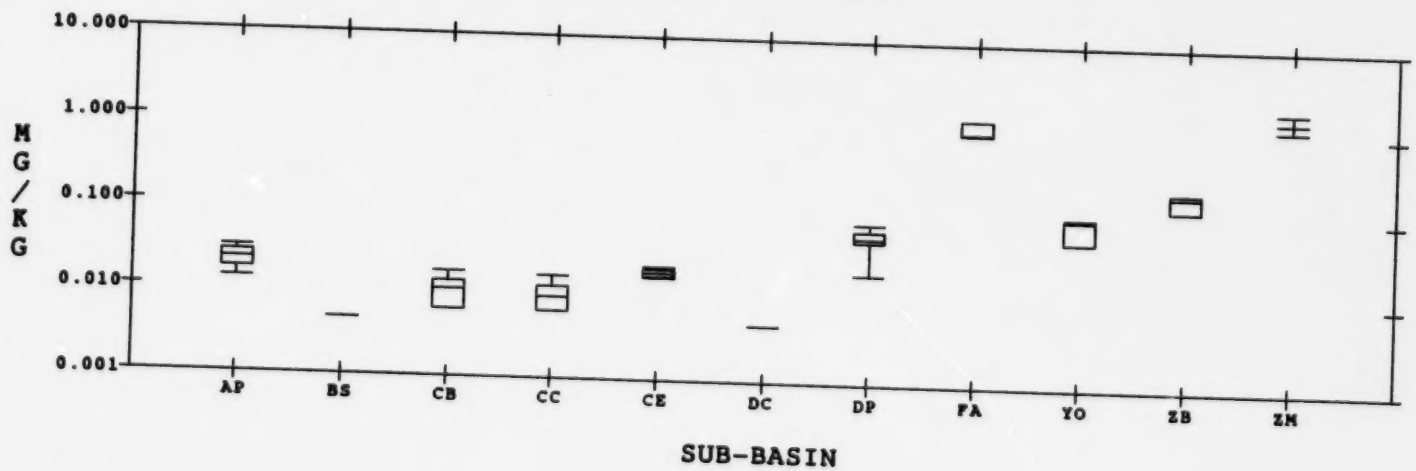


FIGURE 7: POLYCHLORINATED BIPHENYLS IN HARBOUR BOTTOM SEDIMENTS, REPORTED IN MG/KG



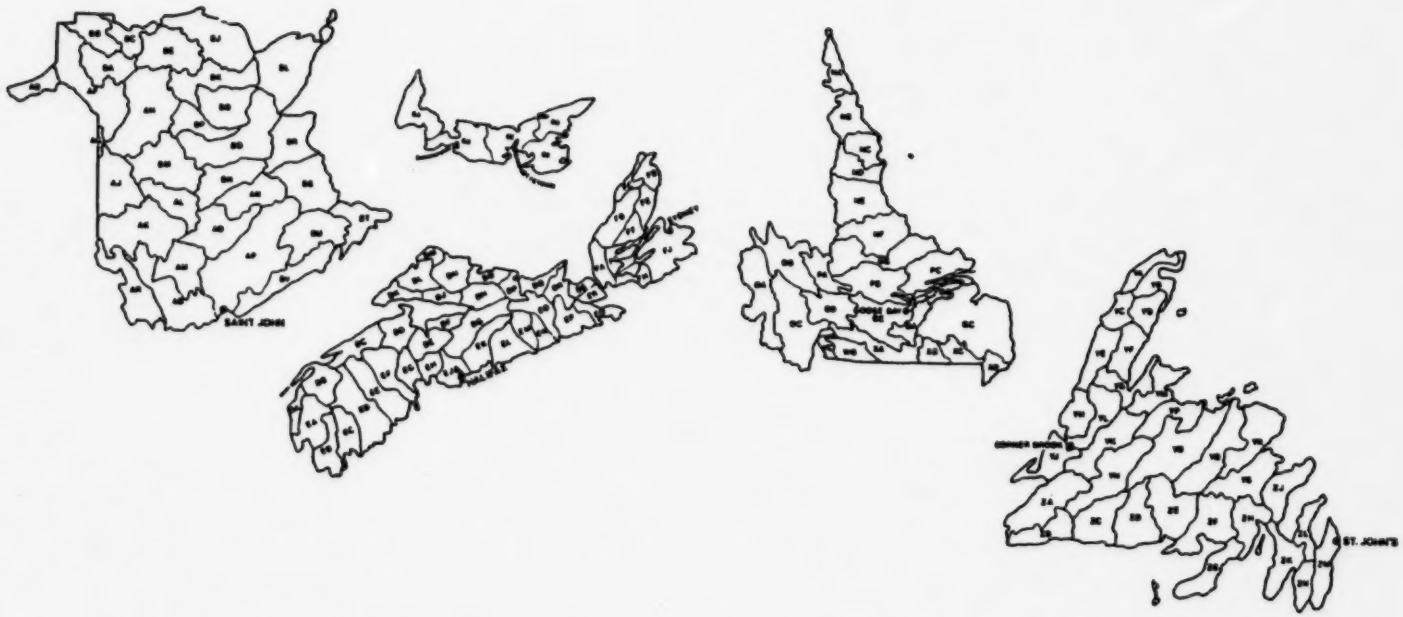
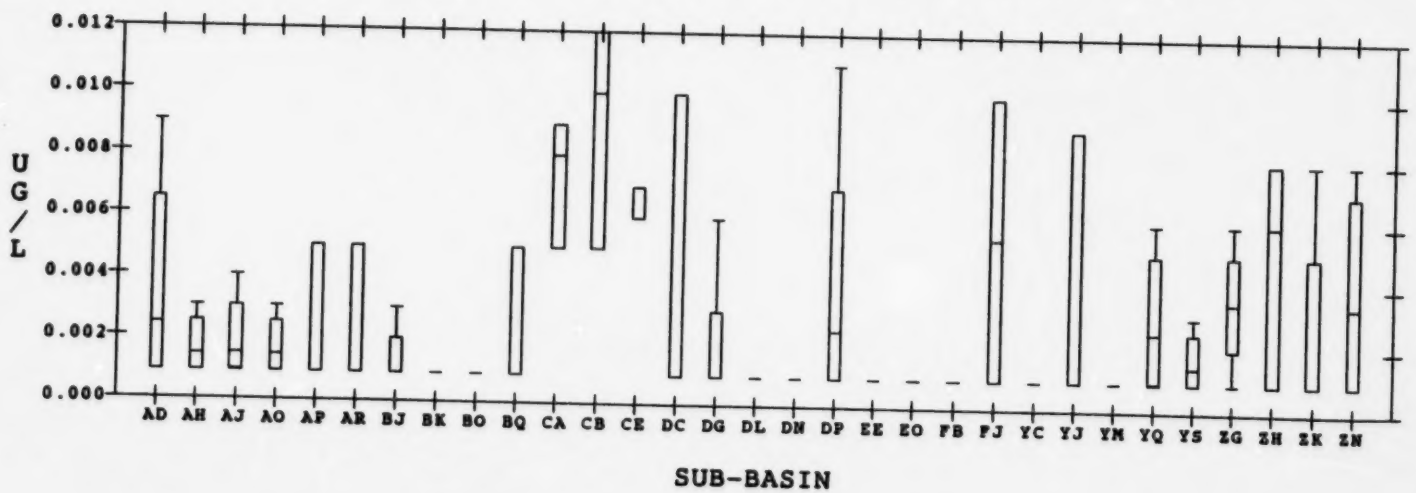


FIGURE 8: FLUORANTHENE IN RIVER WATER, REPORTED IN UG/L


0.012
0.010
0.008
0.006
0.004
0.002
0.000
UG/L
AD AH AJ AO AP AR BJ BK BO BQ CA CB CE DC DG DL DN DP EE EO FB FJ YC YJ YM YQ YS ZG ZH ZK ZN
SUB-BASIN

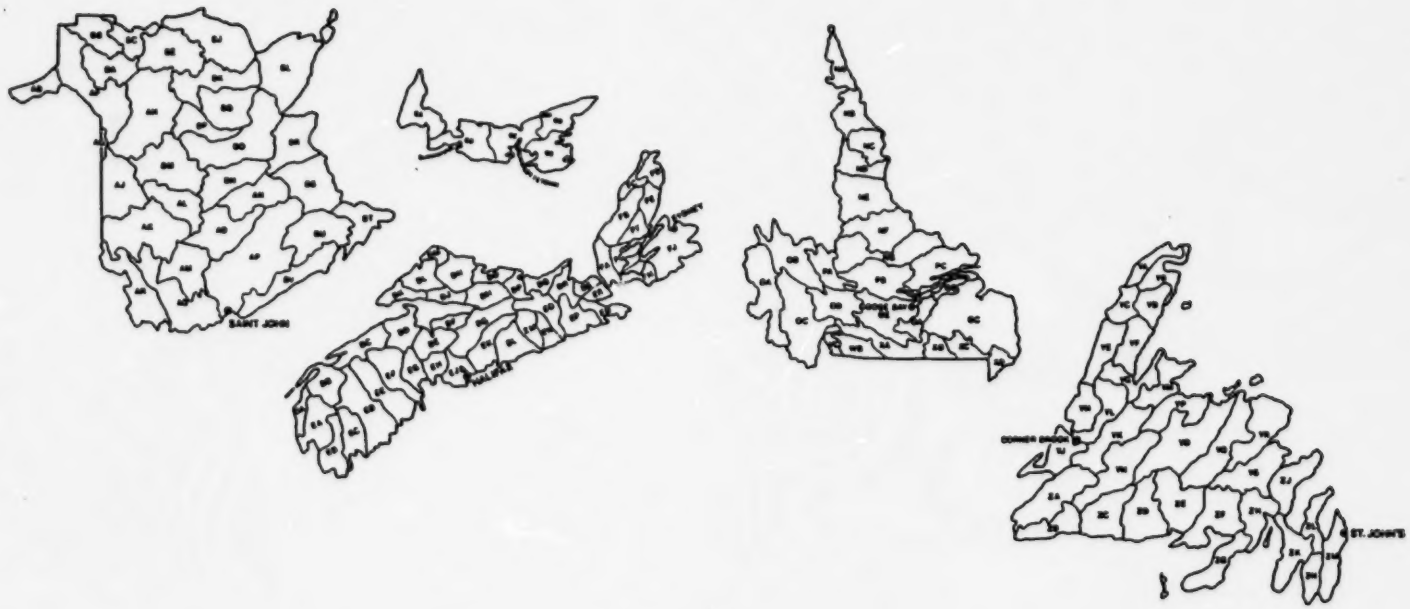
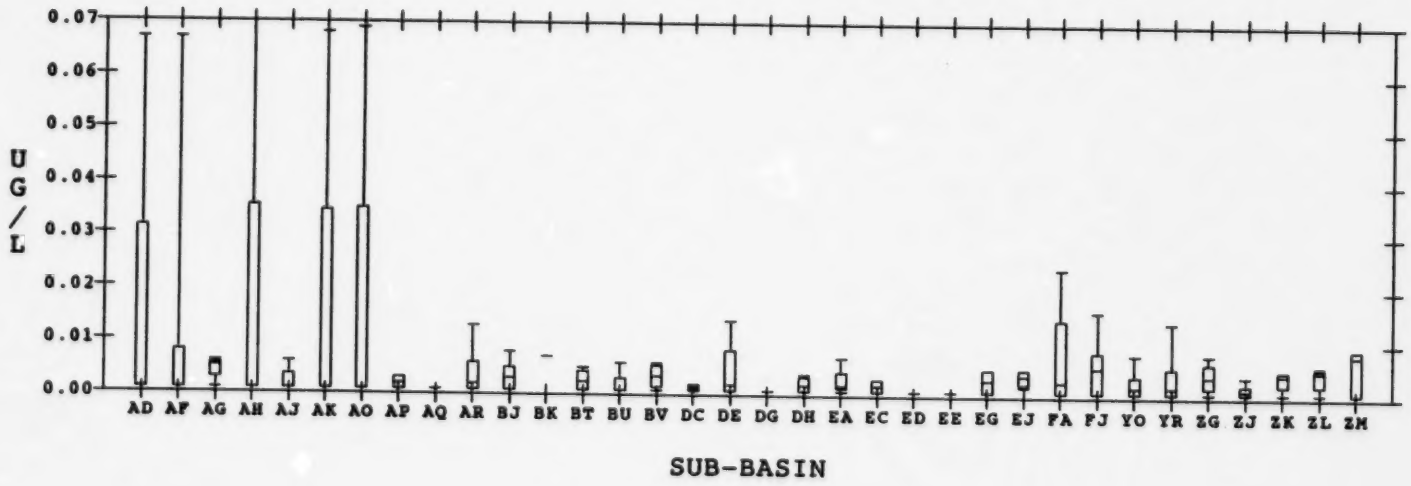


FIGURE 9: FLUORANTHENE IN LAKE WATER, REPORTED IN UG/L


0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
UG/L
AD AF AG AH AJ AK AO AP AQ AR BJ BK BT BU BV DC DE DG DH EA EC ED EE EG EJ FA FJ YO YR ZG ZJ ZK ZL ZM
SUB-BASIN

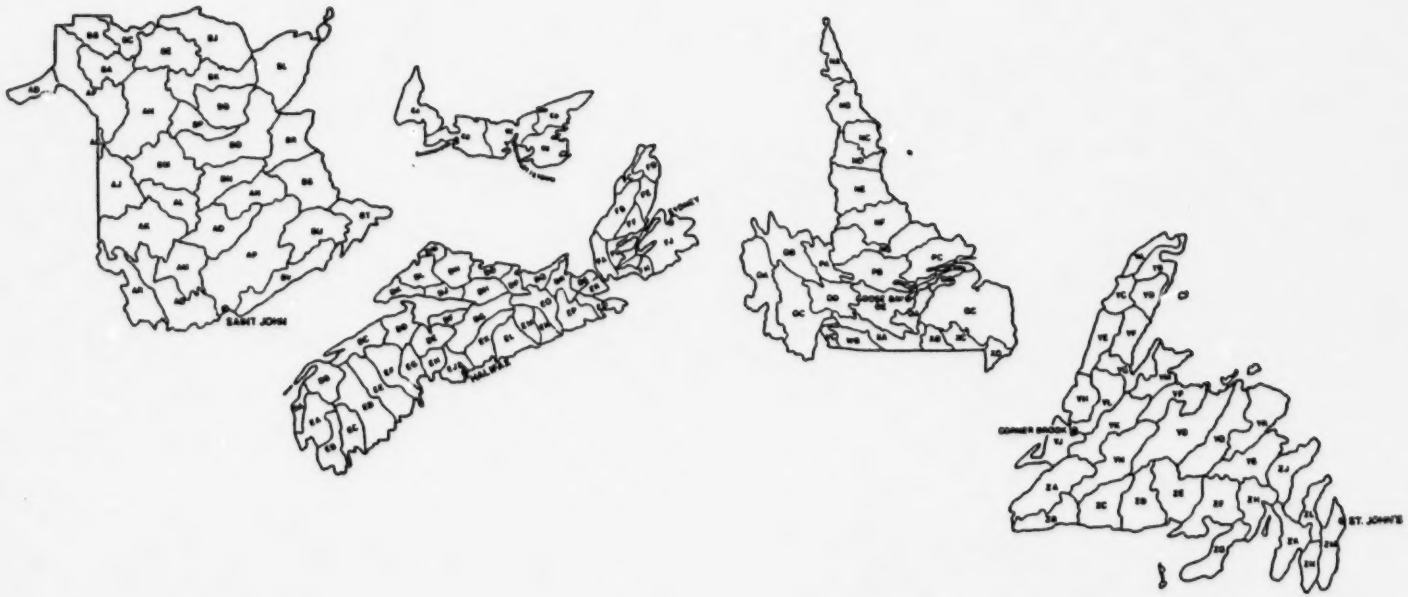
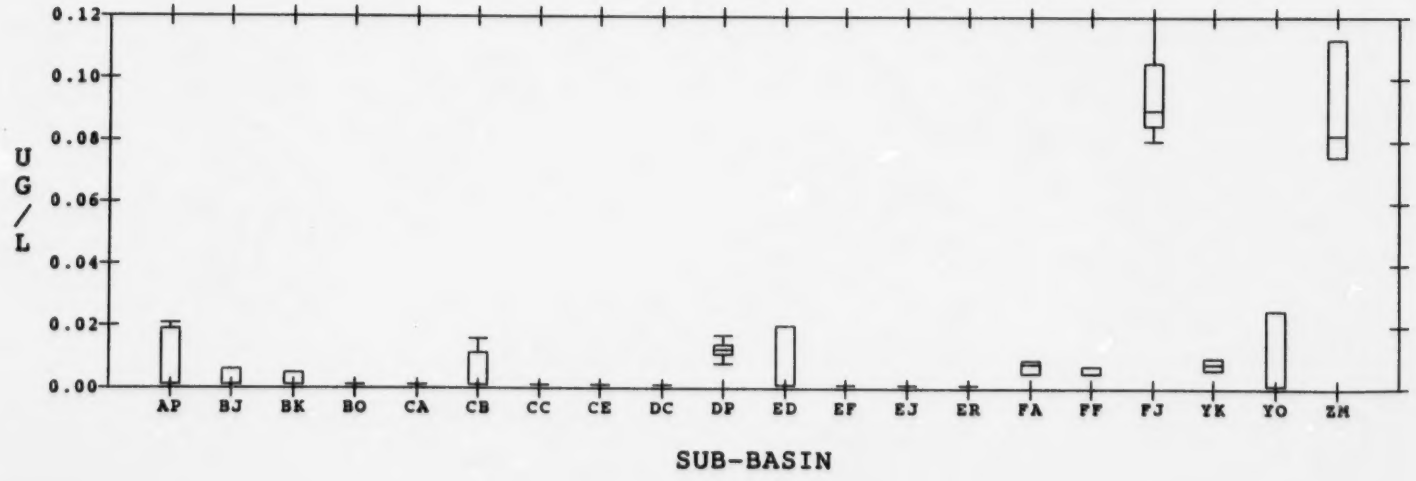


FIGURE 10: FLUORANTHENE IN HARBOUR WATER, REPORTED IN UG/L



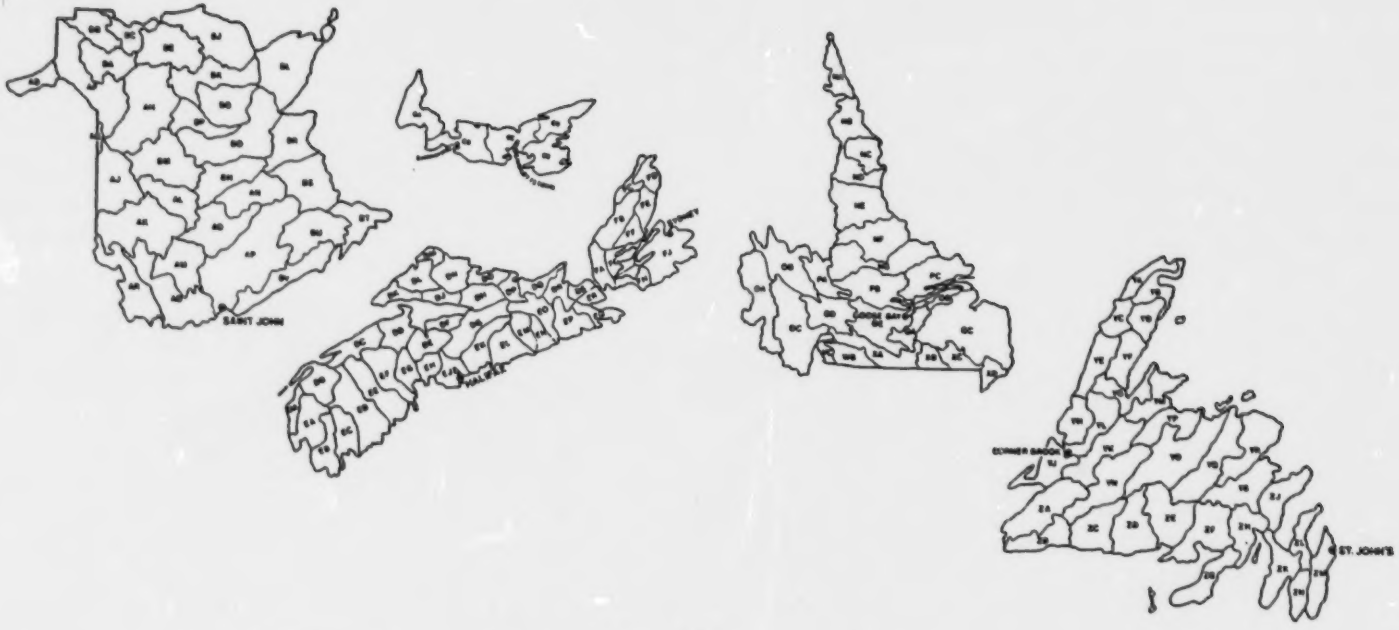
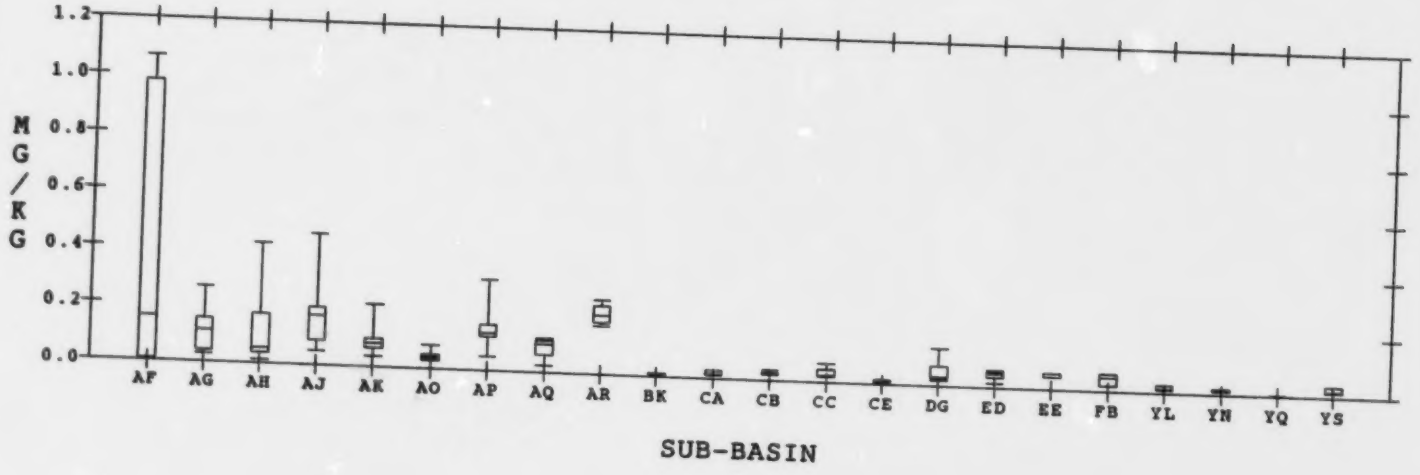


FIGURE 11: FLUORANTHENE IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



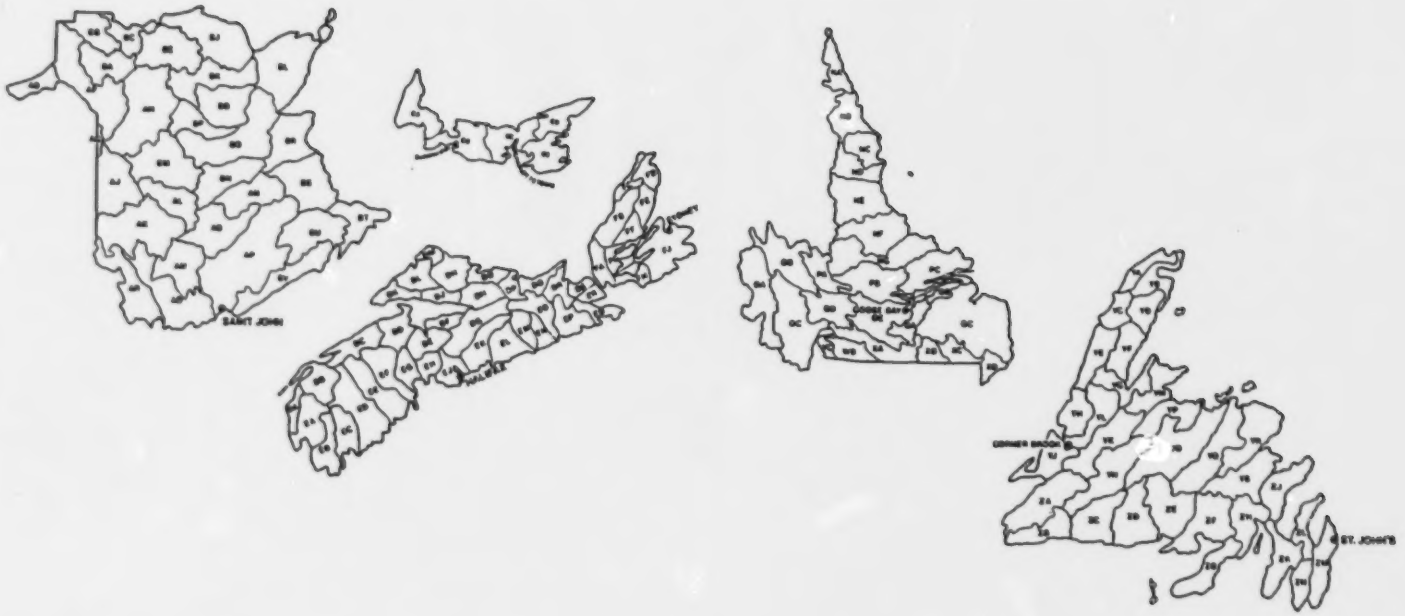
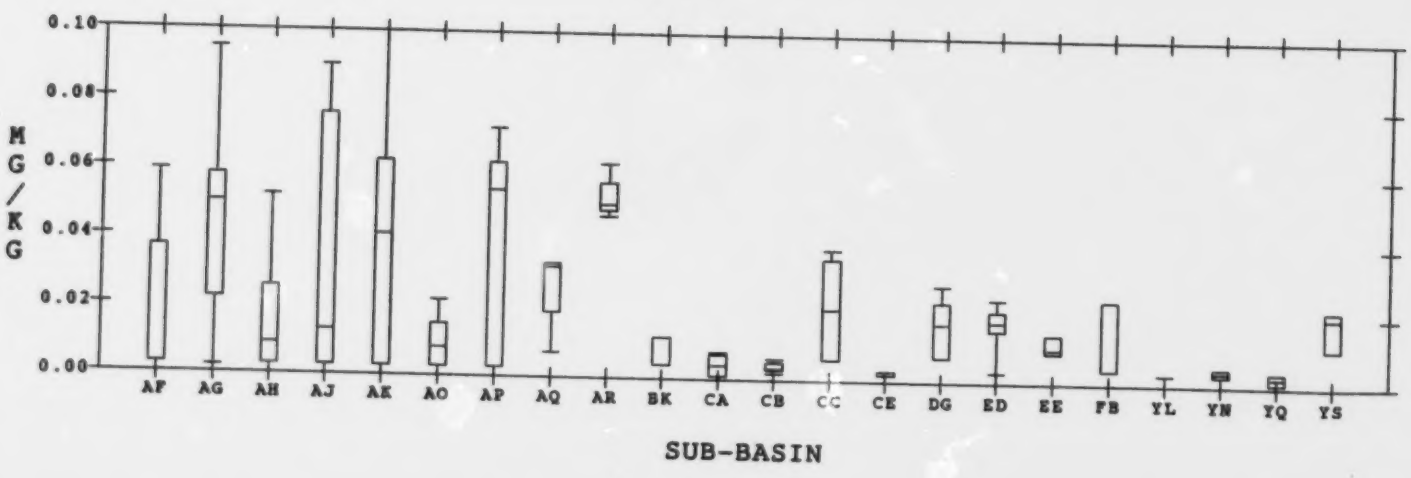


FIGURE 12: BENZO(a)PYRENE IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



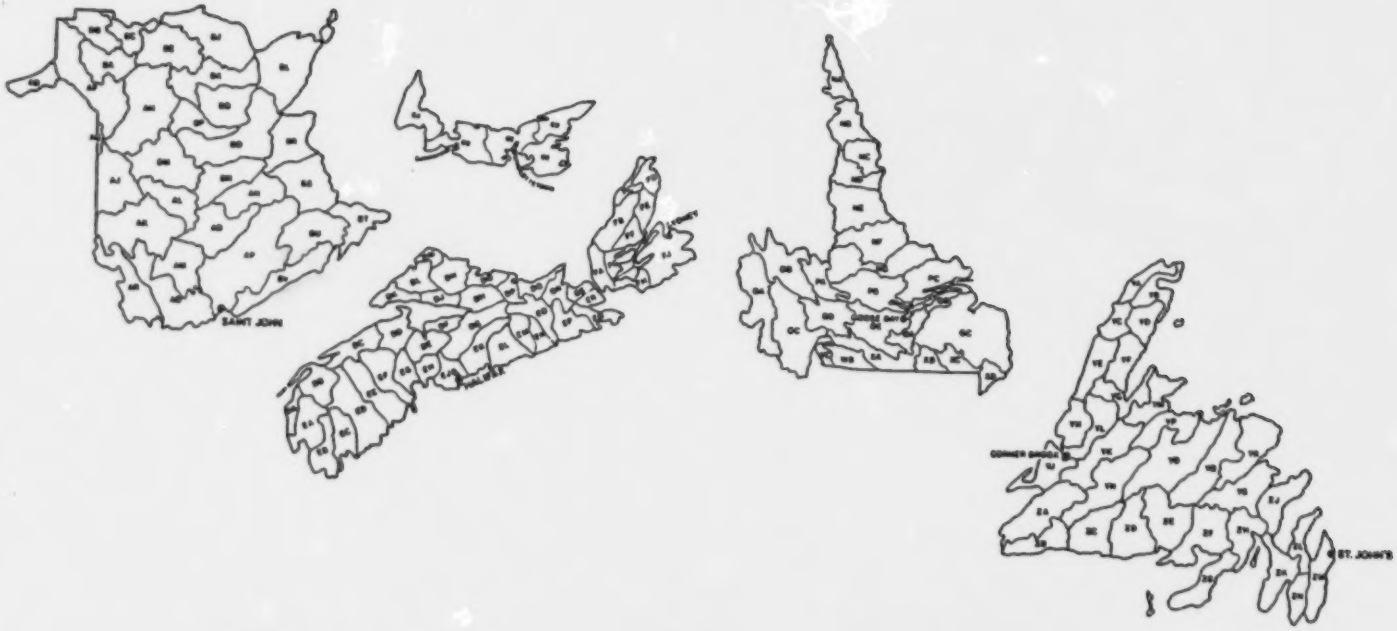
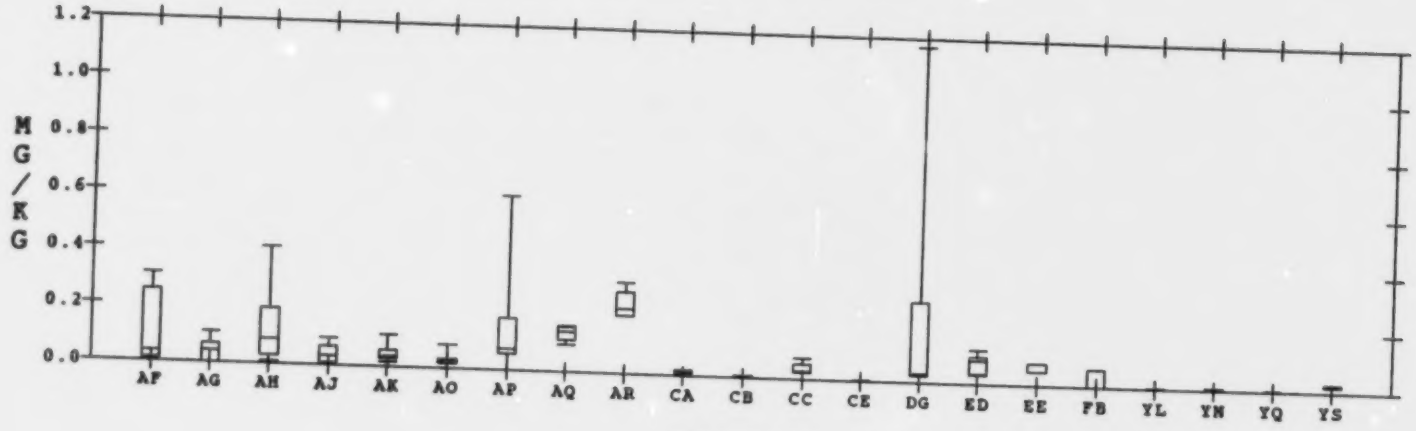


FIGURE 13: BENZO(a)FLUORANTHENE IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



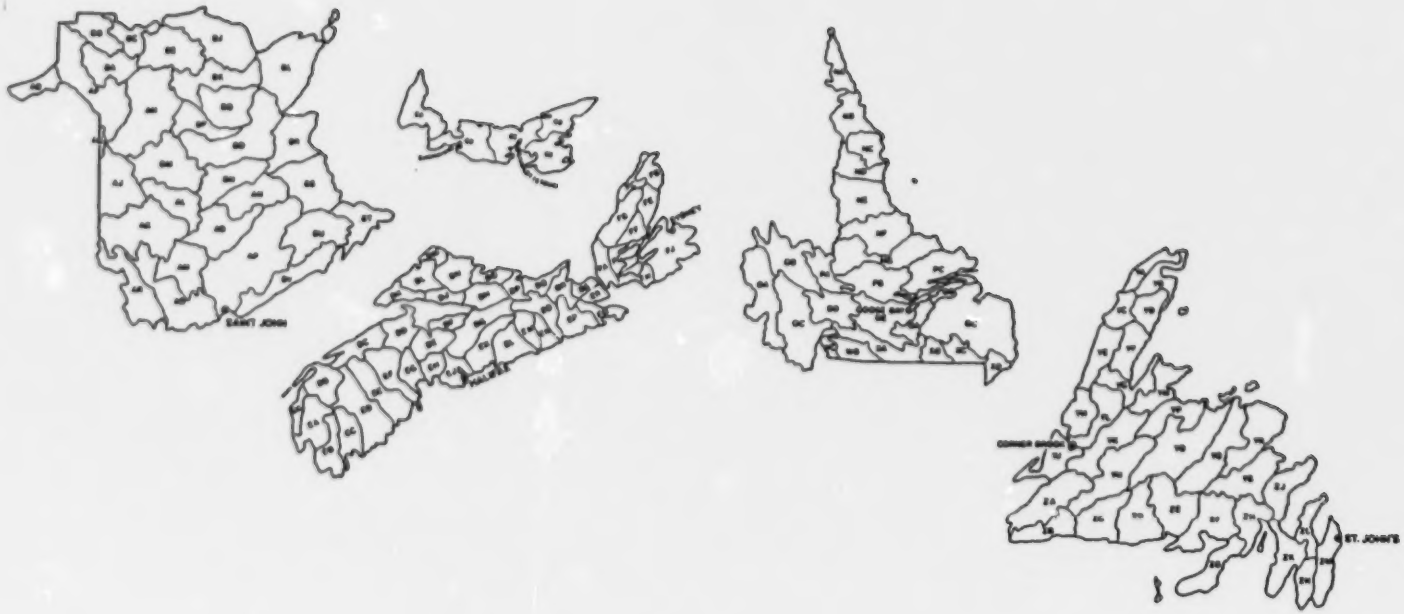
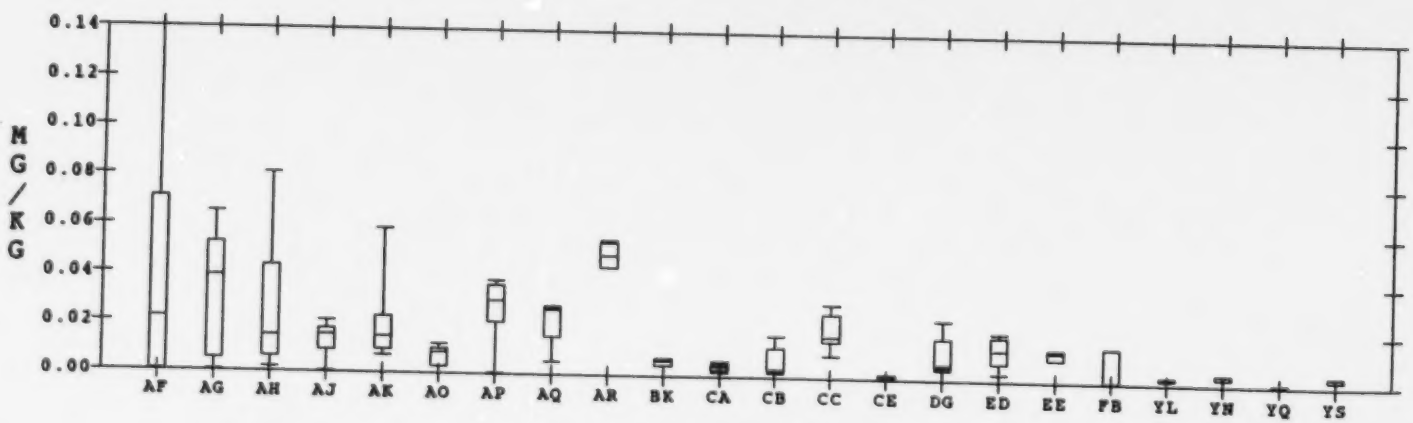


FIGURE 14: BENZO(k)FLUORANTHENE IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



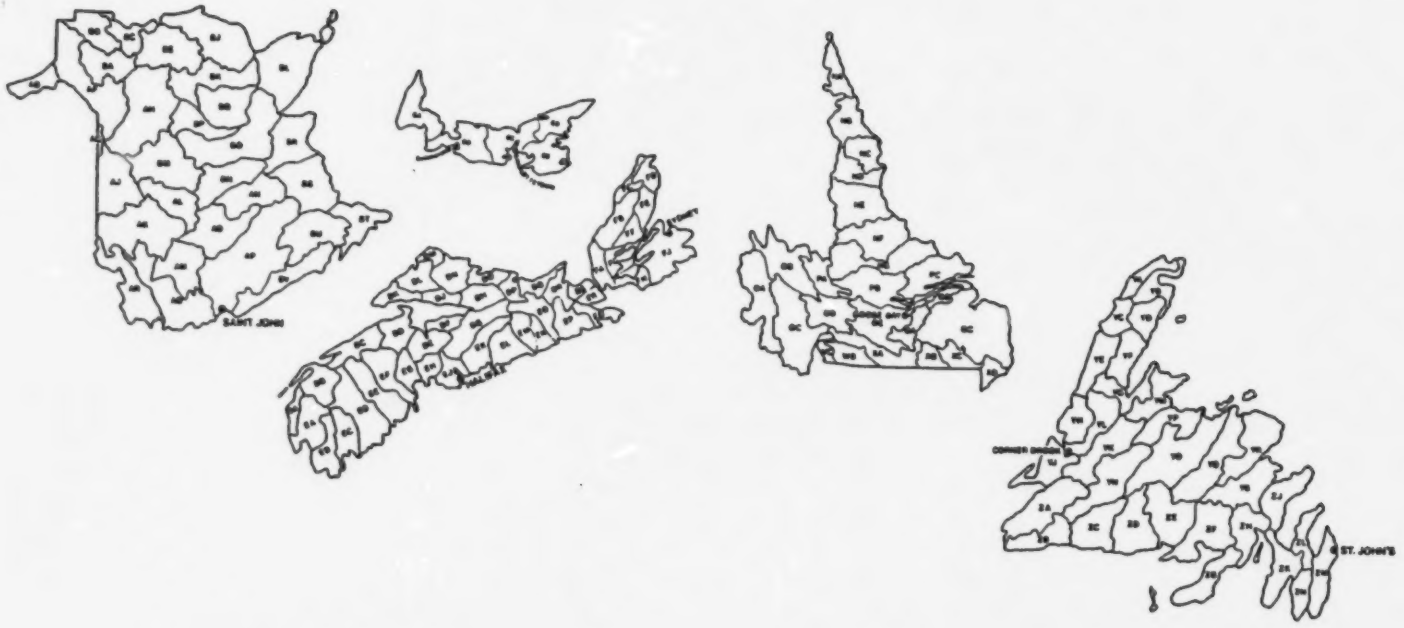
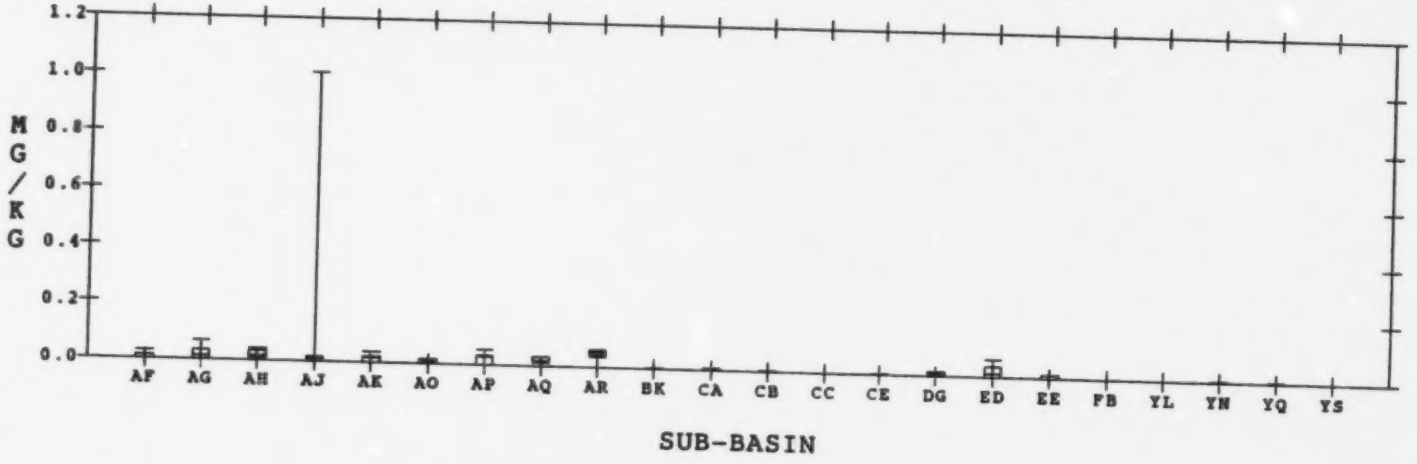


FIGURE 15: BENZO(ghi)PERYLENE IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



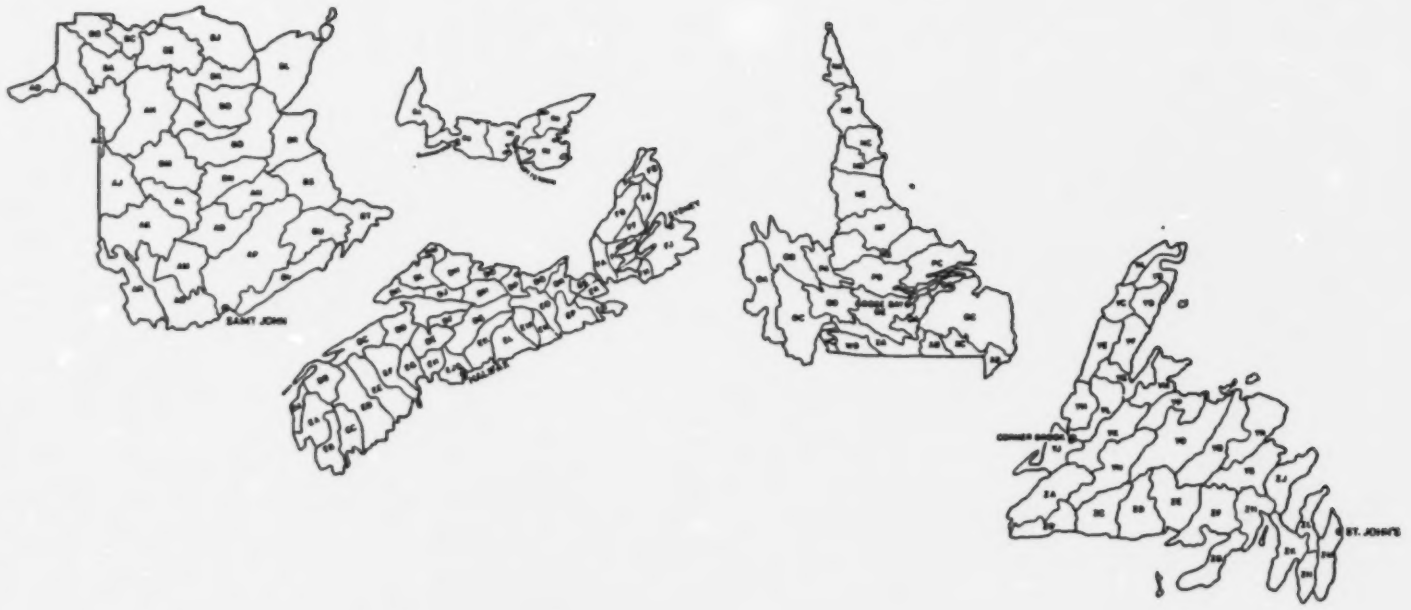
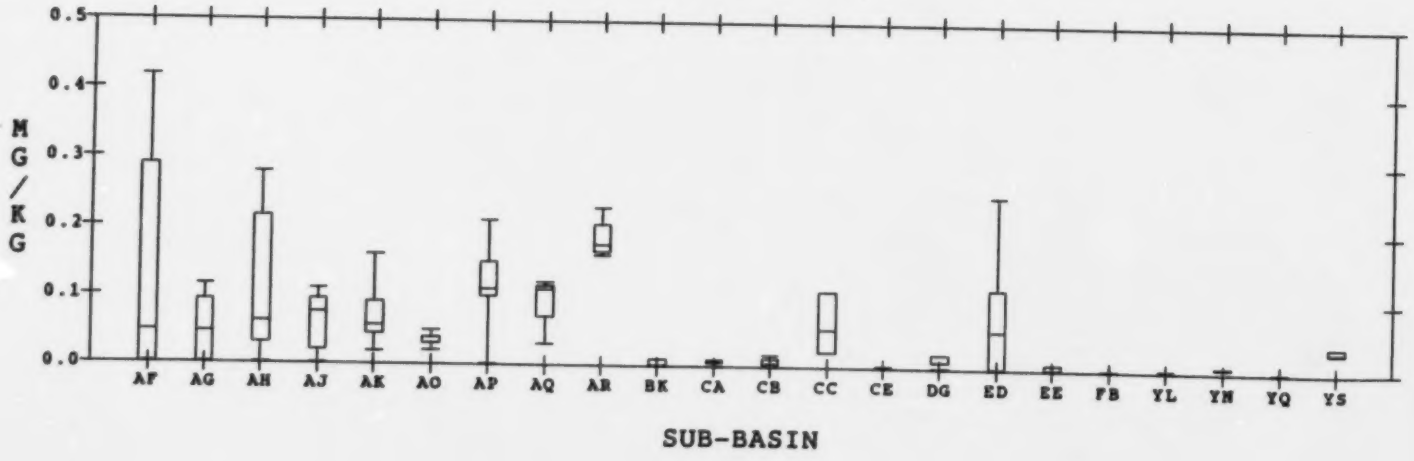


FIGURE 16: INDENO(123cd)PYRENE IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



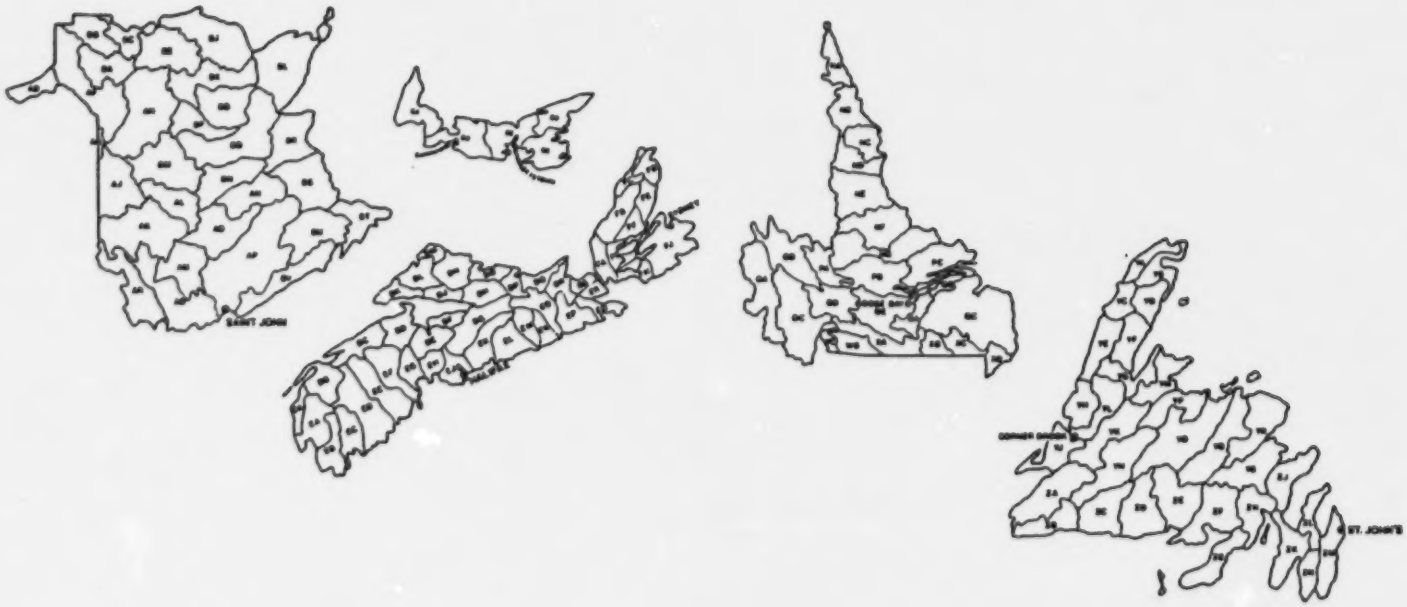
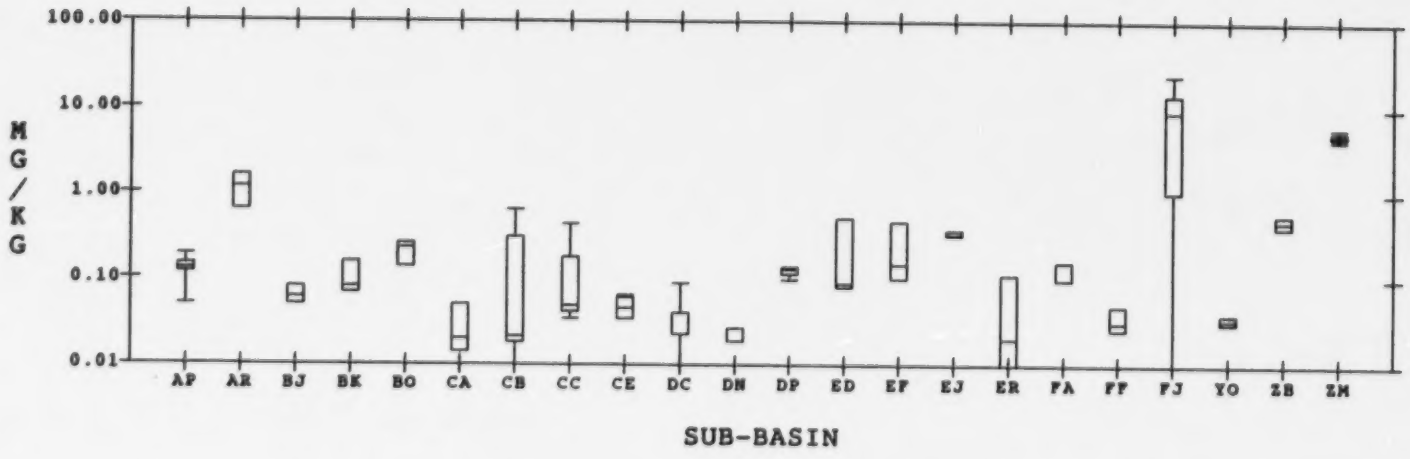


FIGURE 17: FLUORANTHENE IN HARBOUR BOTTOM SEDIMENTS, REPORTED IN MG/KG



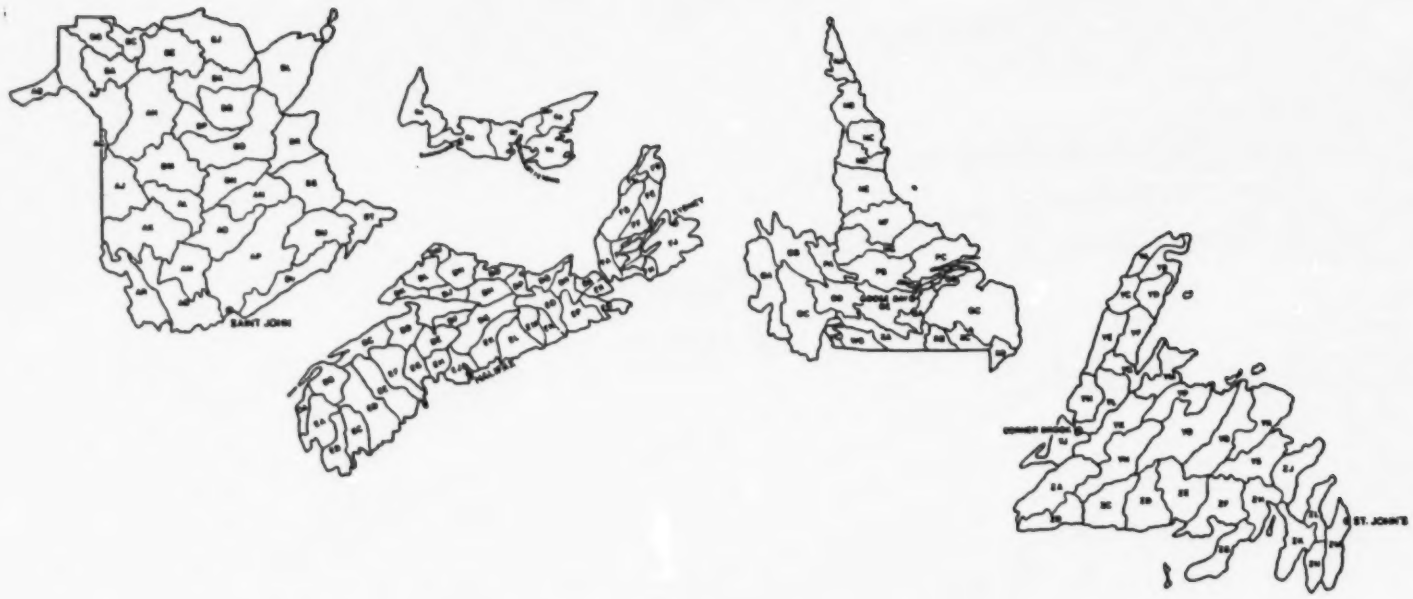
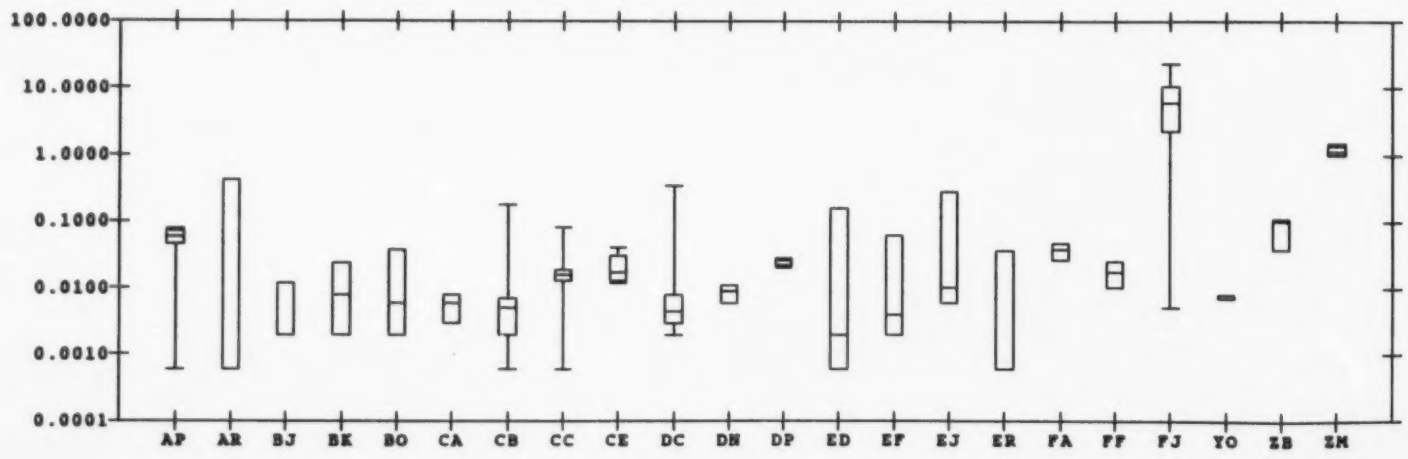


FIGURE 18: BENZO(a)PYRENE IN HARBOUR BOTTOM SEDIMENTS, REPORTED IN MG/KG



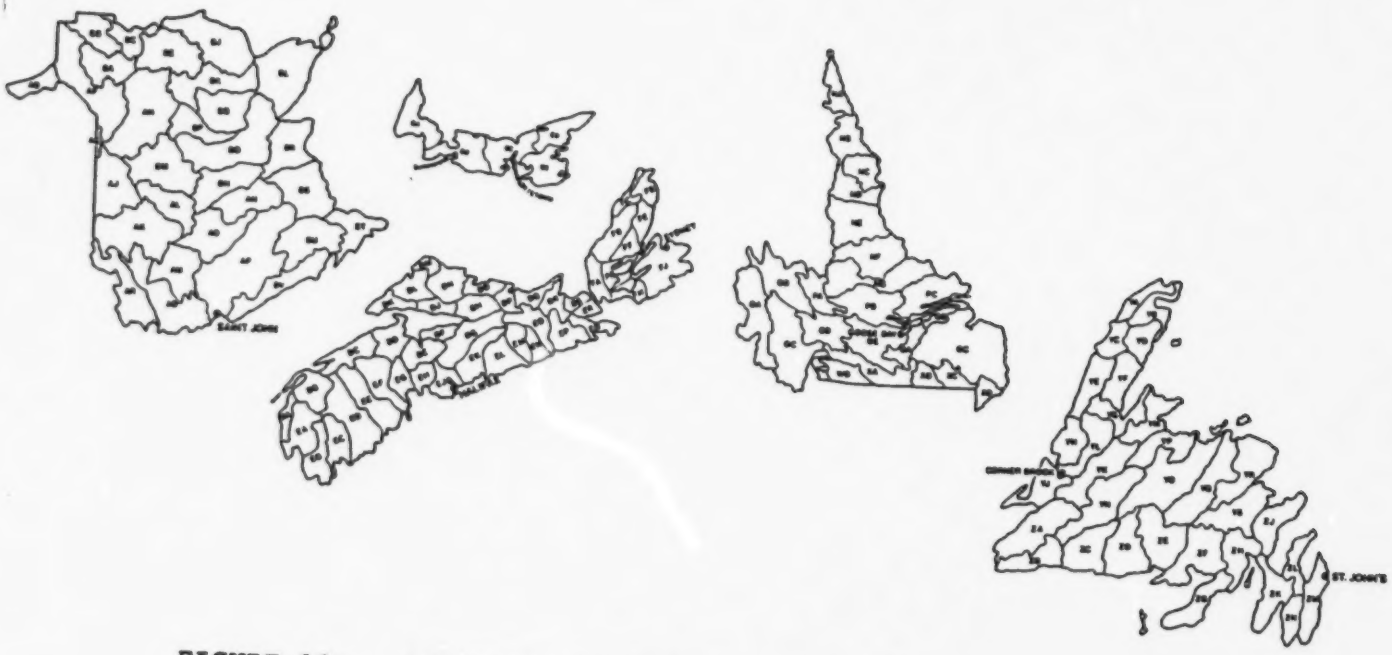
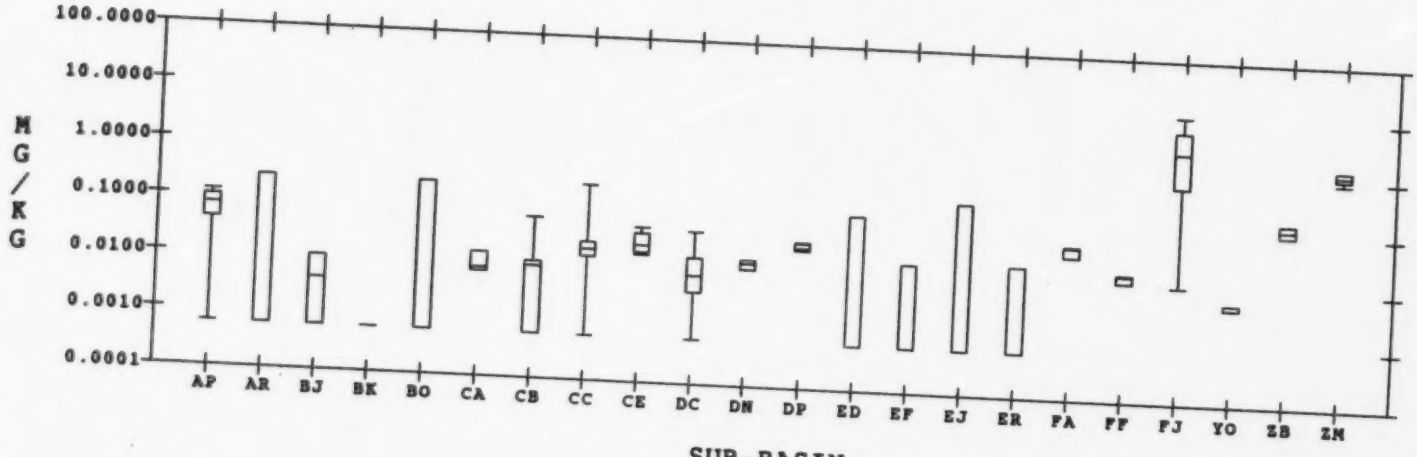


FIGURE 19: BENZO(b)FLUORANTHENE IN HARBOUR BOTTOM SEDIMENTS, REPORTED IN MG/KG



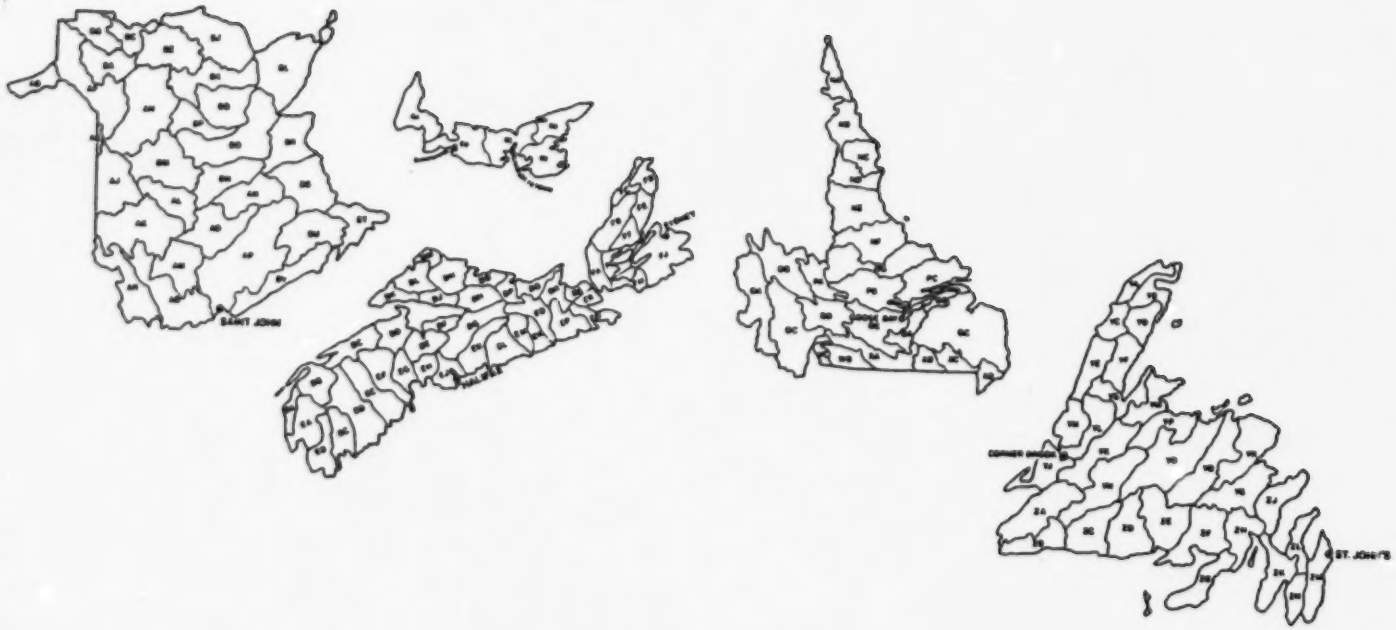
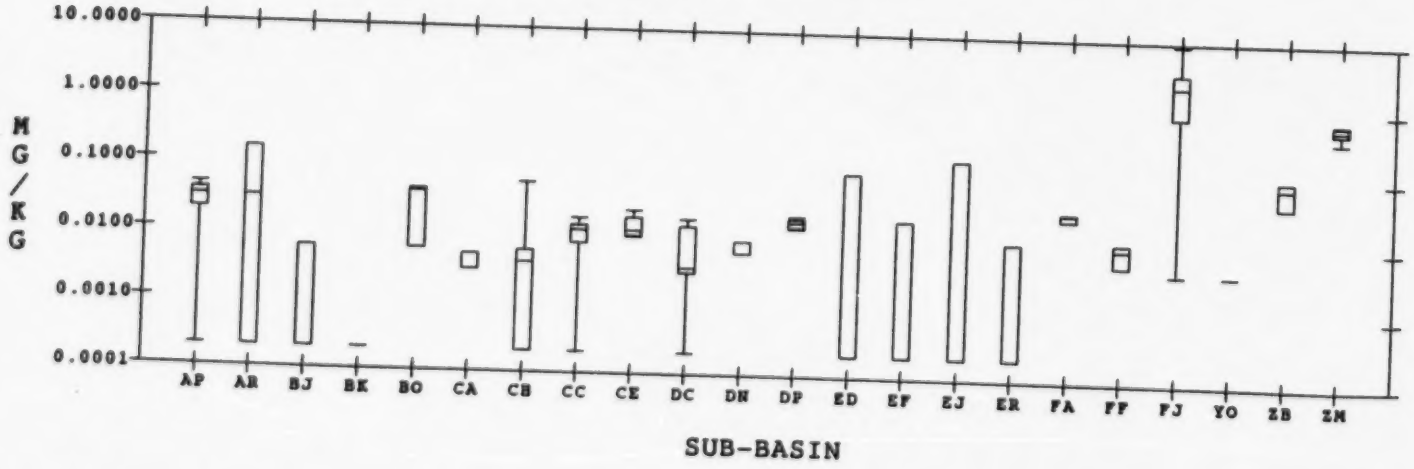


FIGURE 20: BENZO(k)FLUORANTHENE IN HARBOUR BOTTOM SEDIMENTS, REPORTED IN MG/KG



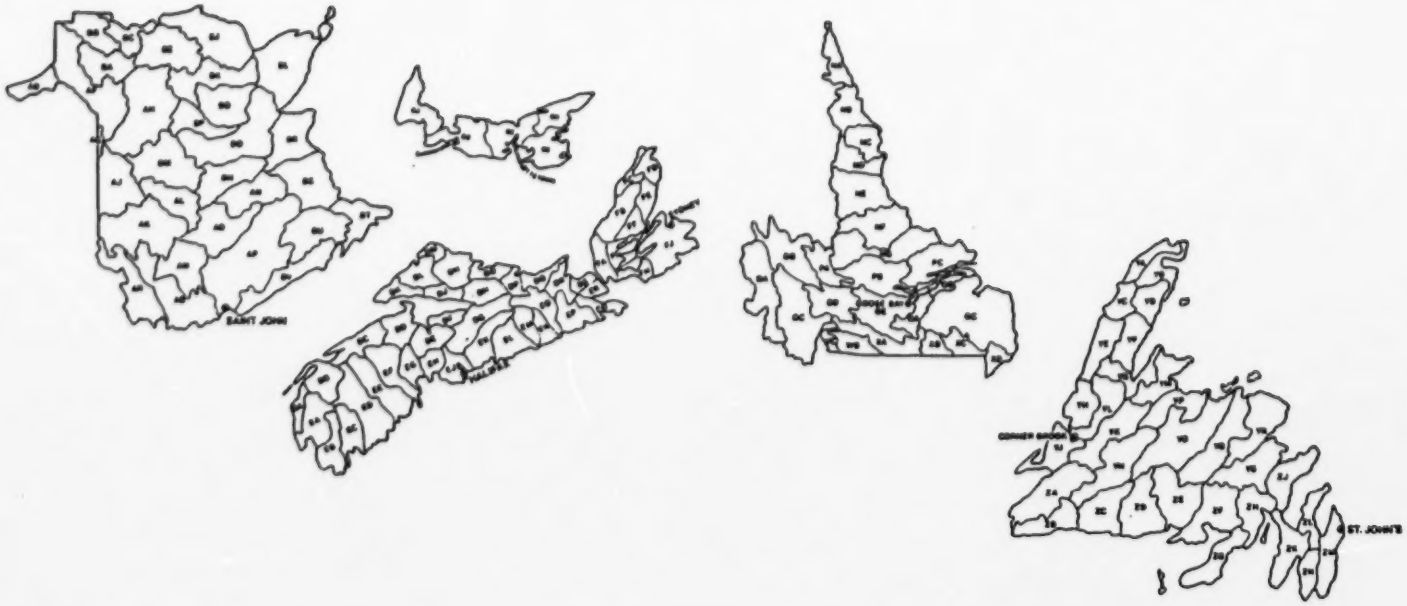
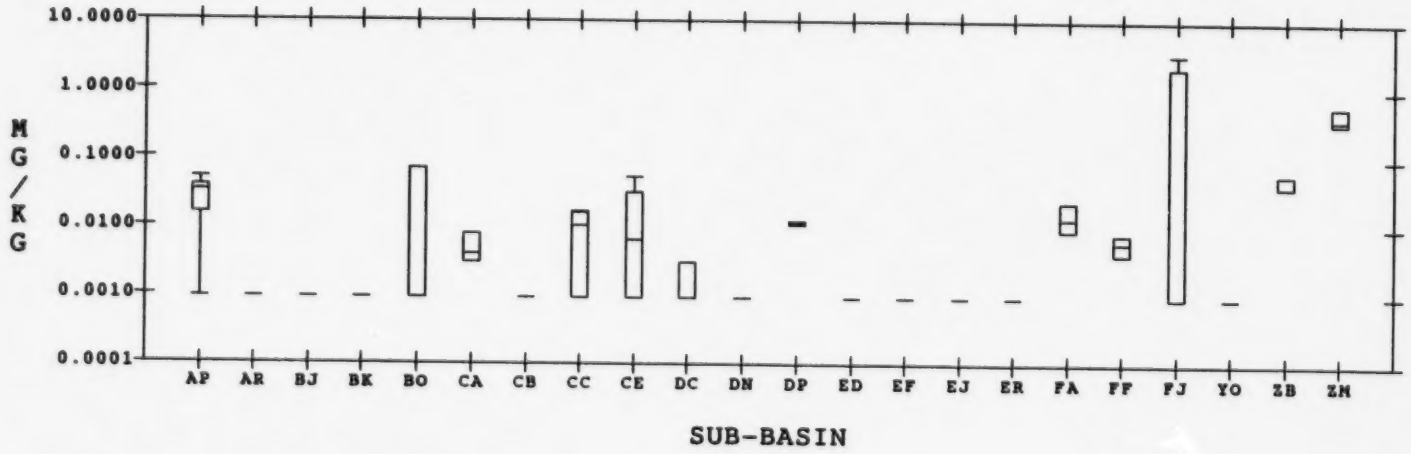


FIGURE 21: BENZO(ghi)PERYLENE IN HARBOUR BOTTOM SEDIMENTS, REPORTED IN MG/KG



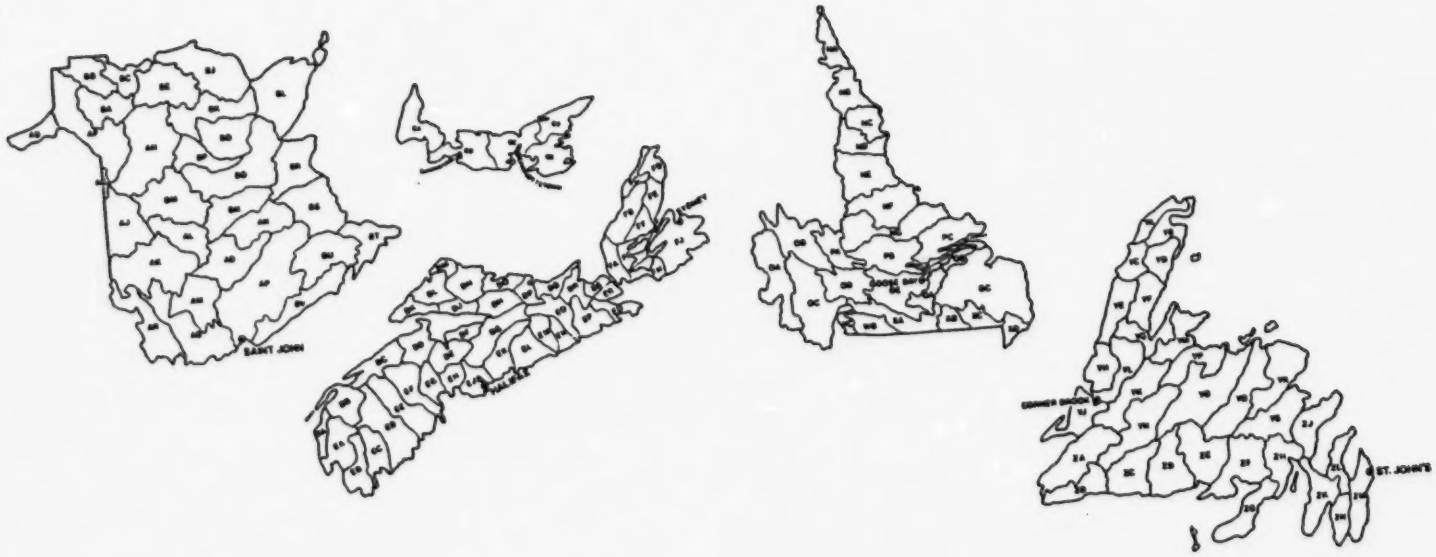
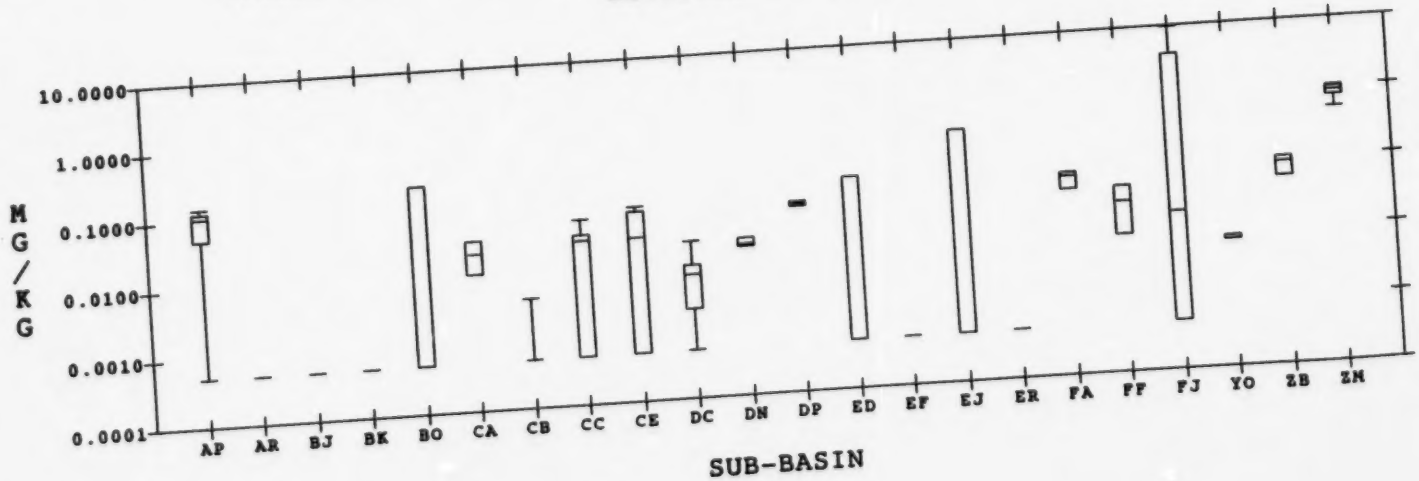


FIGURE 22: INDENO(123cd)PYRENE IN HARBOUR BOTTOM SEDIMENTS, REPORTED IN MG/KG



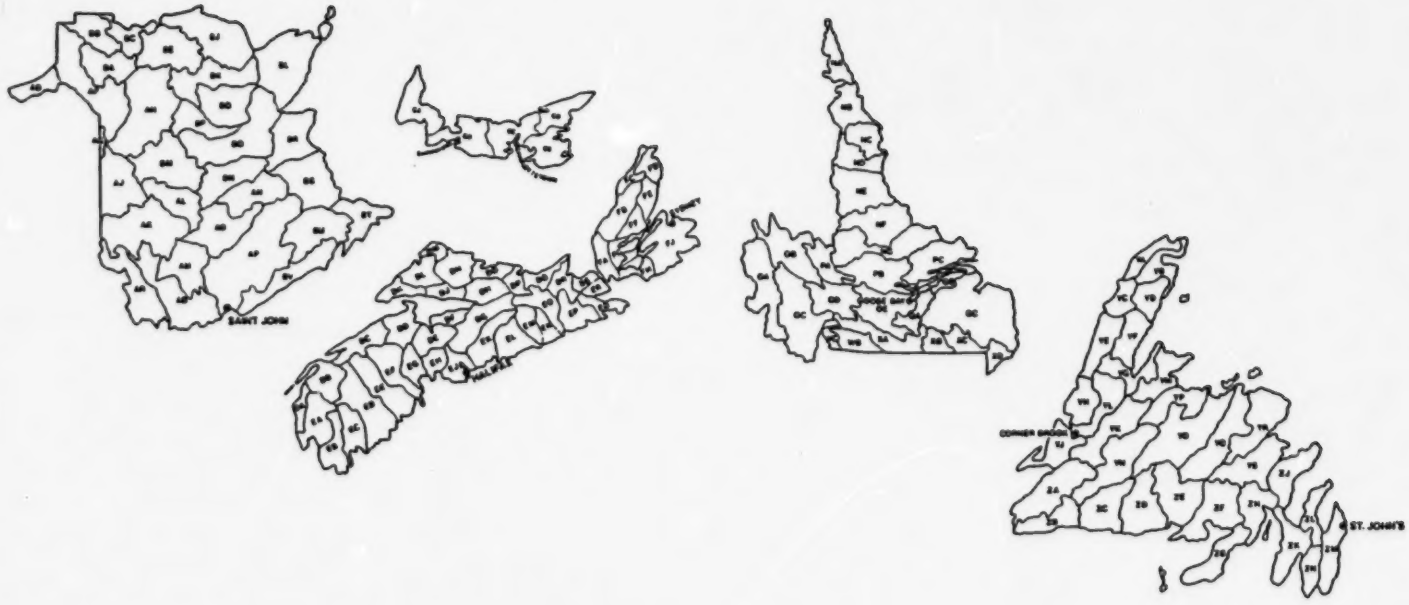
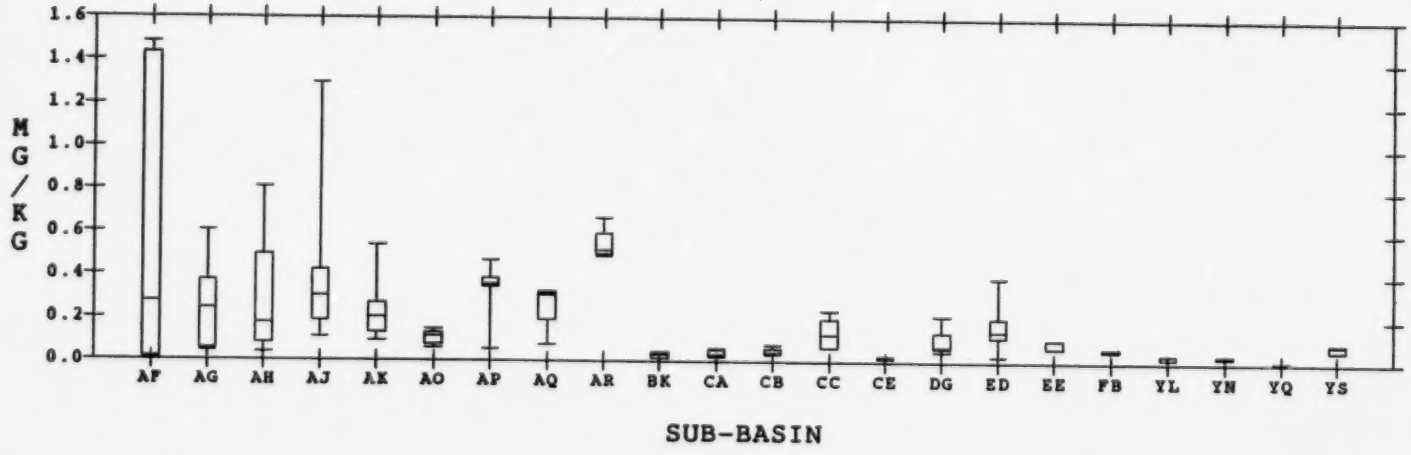


FIGURE 23: TOTAL POLYAROMATIC HYDROCARBONS IN LAKE BOTTOM SEDIMENTS, REPORTED IN MG/KG



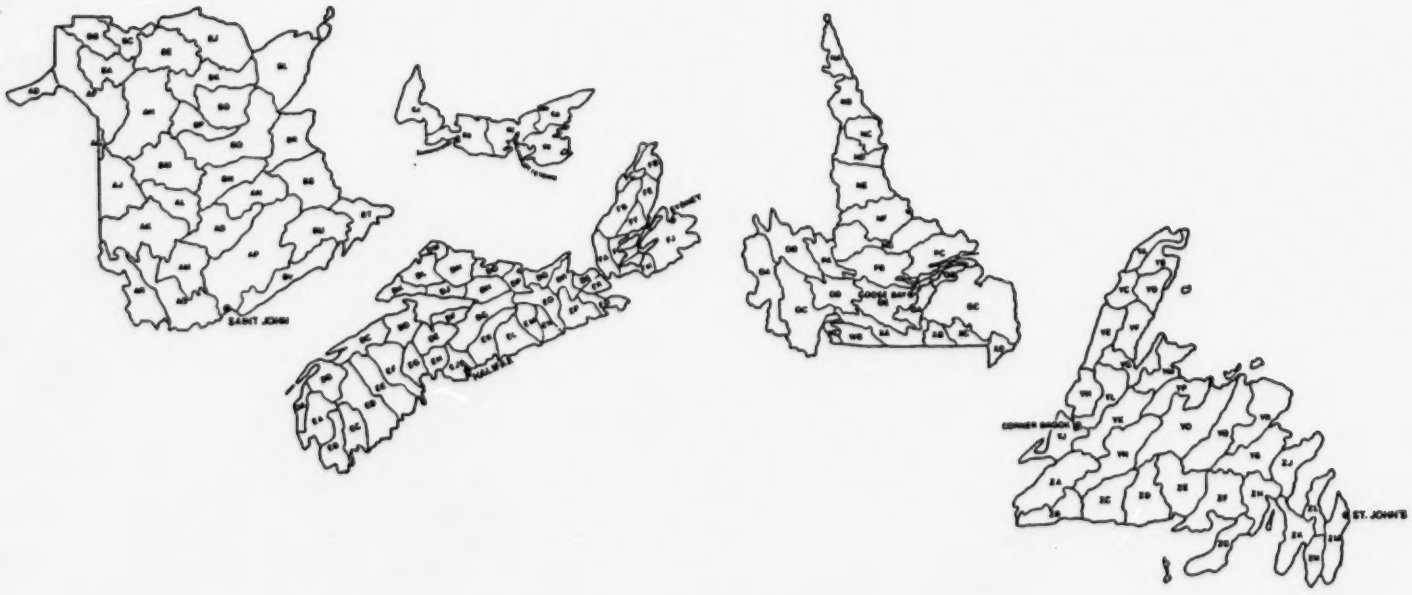
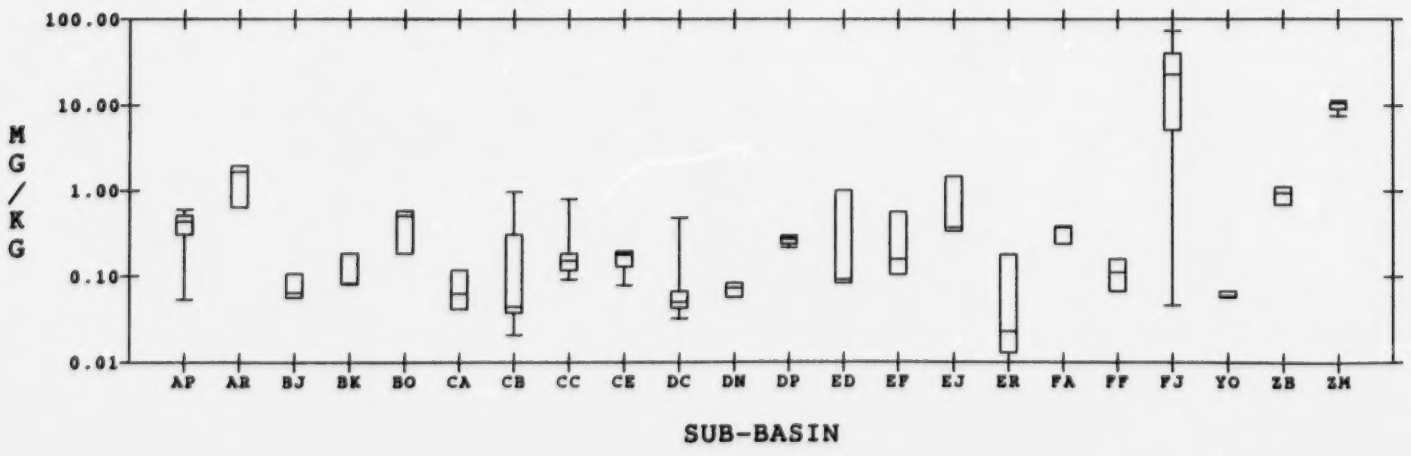


FIGURE 24: TOTAL POLYAROMATIC HYDROCARBONS IN HARBOUR BOTTOM SEDIMENTS, REPORTED IN MG/KG



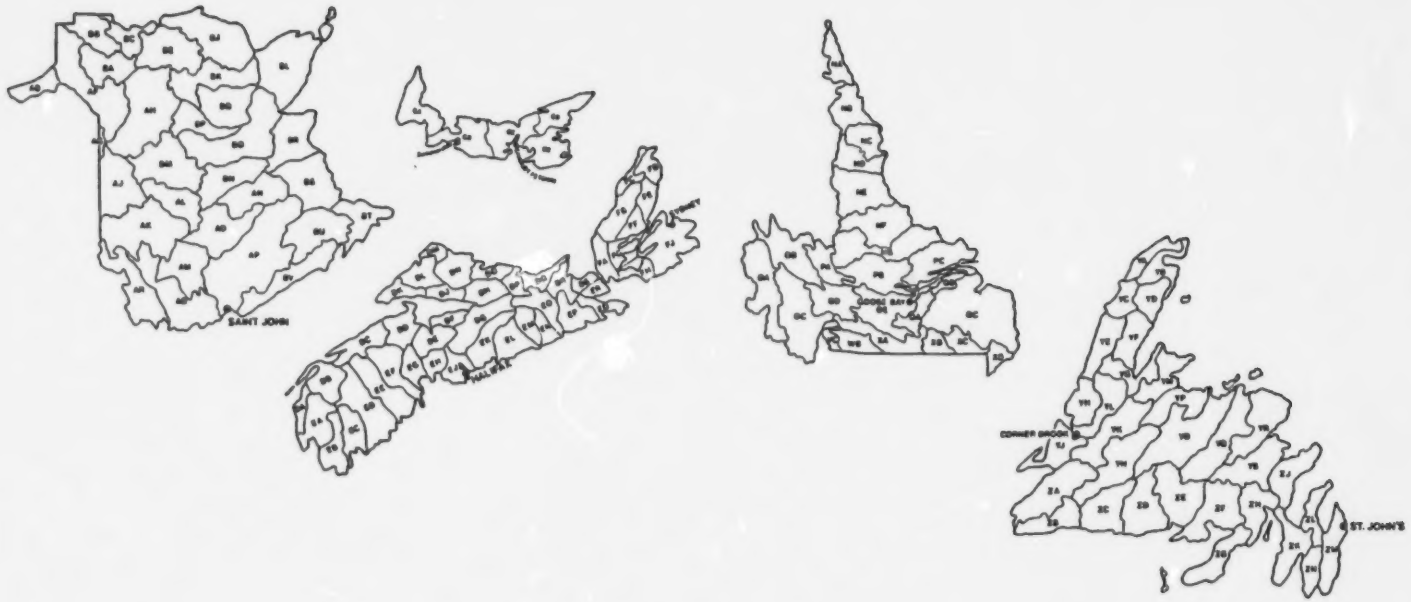


FIGURE 25: TOTAL PHTHALATE ACID ESTERS IN RIVER WATER, REPORTED IN UG/L

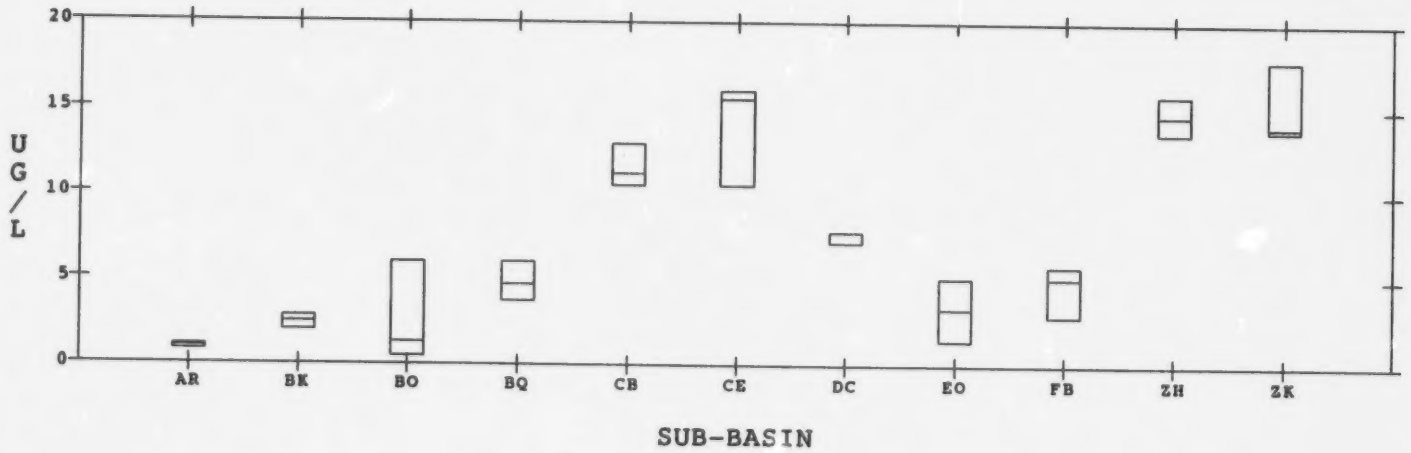


FIGURE 26: TOTAL PHTHALATE ACID ESTERS IN HARBOUR WATER, REPORTED IN UG/L

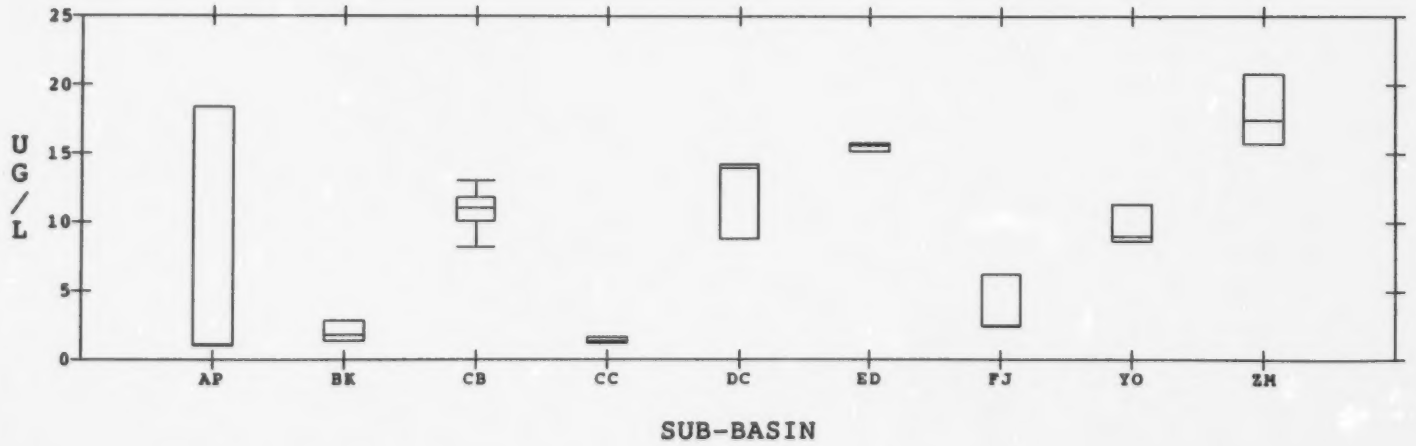
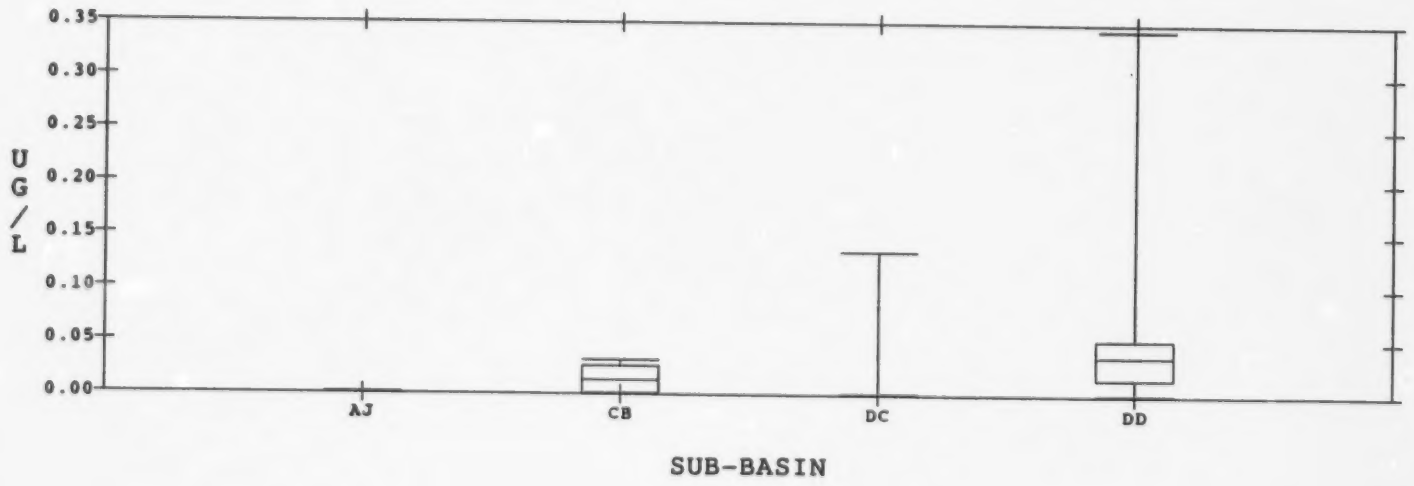


FIGURE 27: ATRAZINE IN RIVER WATER, REPORTED IN UG/L



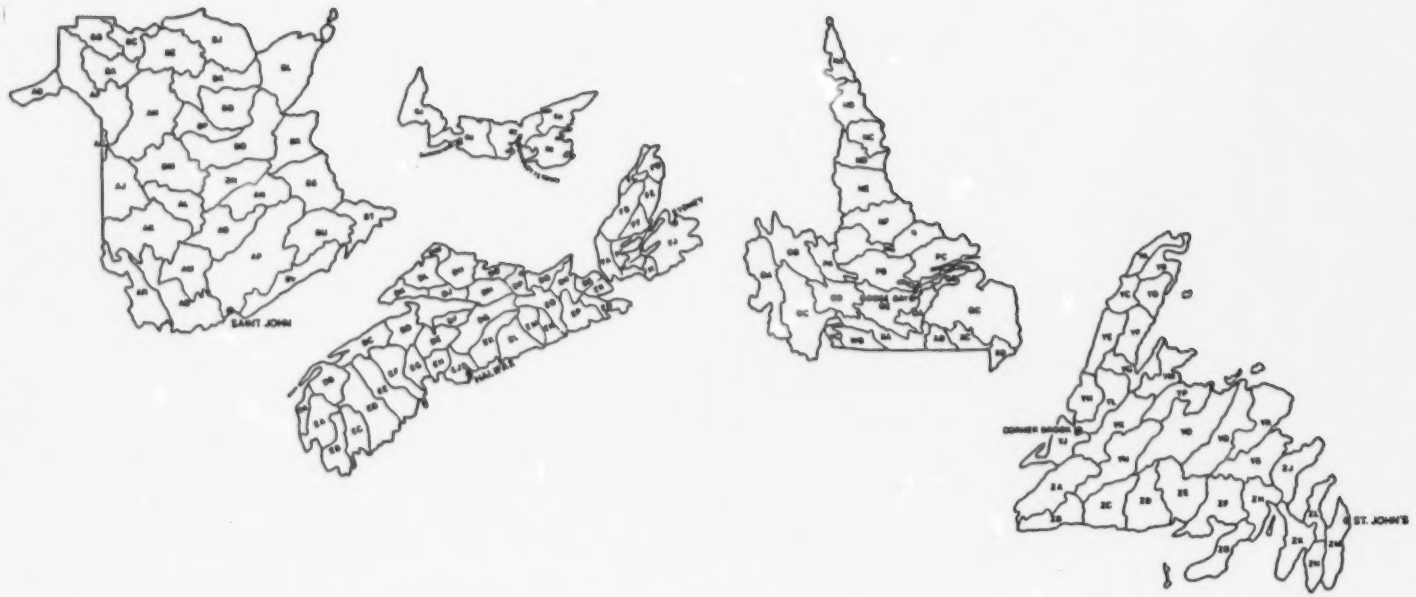


FIGURE 28: ATRAZINE IN LAKE WATER, REPORTED IN UG/L

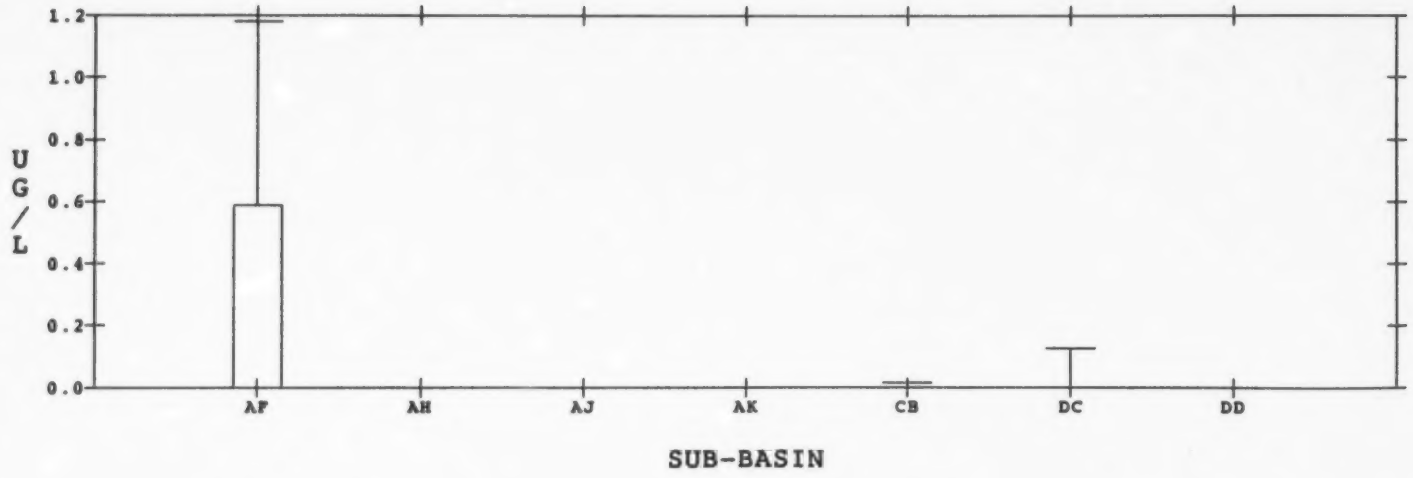


TABLE 1

Organochlorine Insecticides Quantitated
in Water, Sediment, and Biota
by the Water Quality Branch

p,p'-DDT
o,p-DDT
p,p'-DDD
p,p'-DDE
p,p-Methoxy chlor
Heptachlor
Heptachlor epoxide
Alpha-endosulphan
Beta-endosulphan
Alpha-chlordane
Gamma-chlordane
Lindane
Alpha-BHC
Mirex
Aldrin
Endrin
Dieldrin*
Polychlorinated biphenyls**

* Dieldrin not quantitated in sediment and biota due to chemical breakdown in sulphuric acid cleanup.

** PCB are not an organochlorine insecticide but are frequently a companion target chemical. Individual arochlors are quantitated on a project specific basis.

TABLE 2

Polyaromatic Hydrocarbons Quantitated
in Water, Sediment and Biota
by the Water Quality Branch

Fluoranthene	Benzo(k) fluoranthene
Benzo(a) pyrene	Indeno (1,2,3,c,d) pyrene
Benzo(b) fluoranthene	Benzo (g,h,i) perylene

TABLE 3

Triazine Herbicides Quantitated
in Water and Sediment
by the Water Quality Branch

Atrazine

Simazine

Metribuzine

TABLE 4

Carbamate Compounds Quantitated
in Water and Sediment
by the Water Quality Branch

Carbofuran	Aldicarb Sulfoxide
Carbaryl	Aldicarb Sulfone
Aldicarb	Aminocarb

TABLE 5

Chlorinated Phenols Quantitated
in Water
by the Water Quality Branch

2,3-dichlorophenol
2,4-dichlorophenol
2,5-dichlorophenol
2,6-dichlorophenol
3,4-dichlorophenol
3,5-dichlorophenol

2,3,4-trichlorophenol
2,3,5-trichlorophenol
2,3,6-trichlorophenol
2,4,6-trichlorophenol
3,4,5-trichlorophenol

2,3,4,5-tetrachlorophenol
2,3,5,6-tetrachlorophenol

pentachlorophenol

TABLE 6

Chlorinated Benzenes Quantitated
in Water and Sediment
by the Water Quality Branch

1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,2-Dichlorobenzene

1,3,5-Trichlorobenzene
1,2,4-Trichlorobenzene
1,2,3-Trichlorobenzene

1,2,3,5-Tetrachlorobenzene
1,2,4,5-Tetrachlorobenzene
1,2,3,4-Tetrachlorobenzene

Pentachlorobenzene

Hexachlorobenzene

TABLE 7

Chlorophenoxy acid Herbicides Quantitated
in Water and Sediment
by the Water Quality Branch

2,4-D

2,4,5-T

MCPA

TABLE 8

Tri-aryl-phosphates Quantitated
in Water
by the Water Quality Branch

Diphenyl cresyl phosphate

Triphenyl phosphate

Tri-o-tolyl phosphate

Tri-p-tolyl phosphate

TABLE 9

Organophosphorus Pesticides Quantitated
in Water
by the Water Quality Branch

Guthion
Azinphosethyl
Imidan
Disyston
Chlorofenvinphos
Rulene
Parathion
Methyl Parathion
Ronnel
Diazinon
Phorate
Ethion
Carbophenothion
Methyl Trithion
Phosphamidon
Dimethoate
Fenitrothion

APPENDIX A

WATER QUALITY BRANCH
REPORTS AND PUBLICATIONS
RELATED TO TOXIC ORGANIC CHEMICALS

Reprints and publications may be obtained by contacting:

Environment Canada
Inland Waters/Lands Directorate
Water Quality Branch
P. O. Box 861
Moncton, N. B.
E1C 8N6

PRP-016 Analysis of Aminocarb in Water and Sediments by Gas Liquid Chromatography and High Performance Liquid Chromatography

Brun, G.L. and R.M. MacDonald
Presented at Aminocarb Symposium, University of Moncton, Moncton, N.B. (1978)

PRP-026 A Comparative Study of the Use of XAD-2 Resin and the Conventional Serial Solvent Extraction Procedure for the Analysis of Fenitrothion and Some Derivatives in Water-Preservation Techniques.

Mallet, V.N., G.L. Brun, R.M. MacDonald and K. Berkane
Journal of Chromatography 160, 81 (1978)

PRP-031 State of the Art Residue Analysis of Fenitrothion and Aminocarb

Brun, G.L.
1978-79 EMOFICO Report, Fredericton, N.B. (1979)

PRP-032 Determination of Nonyl Phenol in Water and Sediment by High Peformance Liquid Chromatography

Brun, G.L. and R.M. MacDonald
1978-79 EMOFICO Report, Fredericton, N.B. (1979)

PRP-037 Off-Target Fallout of Fenitrothion During 1978 Forest Spraying Operations in New Brunswick

Pearce, P.A., G.L. Brun and J.P. Witteman
Bull. Environm. Contam. Toxicol. 23, 503 (1979)

PRP-038 Techniques Used to Detect Pesticides and Other Similar Chemicals in the Environment

Brun, G.L.
Presented at the New Brunswick Teachers' Association Science Council Conference, Riverview, N.B. (1979)

PRP-043 Summary of Water Quality Branch Pesticide Studies: 1976-1980

Bellivau, P.E.
Water Quality Branch, Inland Waters Directorate, Moncton, N.B., Jul. (1980)

PRP-049 Determination of Aminocarb in Water Quality High Performance Liquid Chromatography

Brun, G.L. and R.M. MacDonald
Bull. Environment Contam. Toxicol. 24, 886 (1980)

PRP-052 1980 Water Quality Branch Pesticide Study

Belliveau, P.E.
EMOFICO Interim Report 1980, Environment New Brunswick, p. 18 (1981)

PRP-060 PCB Contamination at Ellerslie, Prince Edward Island - Interim Report

Brun, G.L. and H.S. Bailey
Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., Dec. (1981)

PRP-066 Data Summary Report for Trace Organics in Precipitation for 1980-81: Kejimkujik Park, N.S. and Ellerslie, P.E.I.

Brun, G.L.
Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., May 27 (1982)

PRP-077 Monitoring of Off-Target Fallout During the Spring Budworm Spray Program

Bailey, H.S. and T.L. Pollock
EMOFICO Interim Report 1982, Environment New Brunswick, pp 45-47 (1983)

PRP-082 Data Summary Report for Trace Organic Contaminants in Precipitation Collected at Kejimkujik National Park, N.S. and Ellerslie, P.E.I. During 1982

Brun, G.L.
IWD-AR-WQB-83-44, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., May 12 (1983)

PRP-088 Survey of Toxic Organic Constituents in the Atlantic Region's Aquatic Environment (1979-81)

Bailey, H.S. and G.D. Howell
IWD-AR-WQB-83-48, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., Oct. 19 (1983)

PRP-096 A PCB Survey of Winter Snowpack in Prince Edward Island: 1982

Brun, G.L. and H.S. Bailey
IWD-AR-WQB-84-54, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., Jan. 5 (1984)

PRP-098 Survey of Toxic Constituents in the Atlantic Region's Aquatic Environment - 1982

Bailey, H.S.
IWD-AR-WQB-84-55, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., Feb. (1984)

PRP-101 Data Summary Report for Trace Organic Contaminants in Precipitation Collected at Kejimkujik National Park, N.S., and Ellerslie, P.E.I. During 1983

Brun, G.L.
IWD-AR-WQB-84-63, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., May 8 (1984)

PRP-114 Preliminary Study of Forestry Herbicide Residues in Northern New Brunswick

Arseneault, R. and W. Ernst
IWD-AR-WQB-85-83, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., (1985)

PRP-116 Data Summary Report on Trace Organic Contaminants in Atlantic Region Precipitation During 1984

Brun, G.L.
IWD-AR-WQB-85-84, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., (1985)

PRP-118 Toxic Chemical Survey: A Survey of Nine Impoundments in the Saint John River Basin

Bailey, Harold S.
IWD-AR-WQB-85-88, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., Sept. (1985)

PRP-124 Assessment of Aquatic Impacts in an Area Treated with Aminocarb at 180 Grams per Hectare

Ernst, W.R., T.A. Clair, and G.R.J. Julien
IWD-AR-WQB-85-94, Water Quality Branch, Inland Waters Directorate, Atlantic Region, Moncton, N.B., (1985)

PRP-136 Etude Preliminaire des Residus D'Herbicide a L'Usage Forestier dans le Nord du Nouveau-Brunswick

Arseneault, Richard and William Ernst
IWD-AR-WQB-85-83, Direction Generale des Eaux Interieures, Conservation et Protection

PRP-145 Pesticide Survey of the Dunk River and Southwest Brook Basins: P.E.I. 198

Clair, T.A., H.J. O'Neill and H.S. Bailey
IW/L-AR-WQB-87-117, Inland Waters/Lands Directorate, Environment Canada, Water Quality Branch, Moncton, N.B., Mar. (1987)

PRP-146 Off-Target Fallout of the Insecticides Fenitrothion and Aminocarb During the Spruce Budworm Spray Program in New Brunswick, 1980-1983

O'Neill, H.J. and H.S. Bailey
IW/L-AR-WQB-87-124, Inland Waters/Lands Directorate, Environment Canada, Water Quality Branch, Moncton, N.B., Mar. (1987)

PRP-148 Sediment and Biota from Five Labrador - Quebec Transboundary Basins

Lockerbie, D.M.
IW/L-AR-WQB-87-120, Inland Waters Directorate, Environment Canada, Water Quality Branch, Moncton, N.B., Mar. (1987)

APPENDIX B

DISTRIBUTION OF SAMPLES QUANTITATED AND CONTAMINANT GROUPINGS

The media type versus parameter group table presents the total number of samples analyzed for a chemical group along with the numbers of samples for the three principal surface water grouping used in the text. In many cases the chemical groups overlap, as some samples were quantitated for several parameter groups. The total encompasses all programs that involve analysis of toxic organic chemicals and includes groundwater sources, precipitation samples, and quality assurance samples. It does not include those samples that may have been done for an outside organization. This accounts for the apparent difference between the total samples and surface water types.

Biota samples were quantitated for organochlorines and polychlorinated biphenyls only due to the lipophylic nature of the chemicals.

The PCB, OC, OP and PAH groups may be extracted using the same procedure producing a common extract but must be quantitated on different instruments. All other chemical groups have individual group specific extraction and quantitation methodologies.

It should also be kept in mind that the majority of the samples were not only for multiple group analysis, but also that each chemical group represents from 3 to 18 different individual parameters as illustrated by Tables 1 to 9.

MEDIA DISTRIBUTION vs PARAMETER GROUP

	PCBs	OCs[1]	OPs[2]	PAHs[3]
Total Water Samples	782	782	470	739
Stream	124	124	154	151
Lake	221	221	218	190
Estuary + Harbour	17	17	10	85
Total Sediment Samples	476	476	268	258
Stream	58	58	50	9
Lake	311	311	209	142
Estuary + Harbour	94	94	8	100
Total Biota	301	301	N.T.[4]	29

1 Polychlorinated biphenyls and organochlorine pesticides analyses are commonly performed at the time using the common extract.

2 Organophosphorus insecticides, includes water samples from Budworm Program but does not include XAD-4 resin columns.

3 Polyaromatic hydrocarbons

4 N.T. indicates media not tested for that group

	CBs[5]	CPs[6]	TZ[7]	Carb[8]
T.H_2O	682	373	128	531
Stream	197	106	60	169
Lake	229	158	59	233
Estuary + harbour	119	19	3	36
T. Sed	74	N.T.	451	451
Stream	Nil	-	73	73
Lake	9	-	314	314
Estuary + Harbour	65	-	451	451 451
T. Biota	N.T.	N.T.	N.T.	N.T.

5 Chlorinated benzenes
6 Chlorinated phenols
7 Triazine herbicides
8 Cabamate herbicides

	PAE[9]	TAP[10]	Phenoxy[11]
T. H_2O	139	140	137
Stream	68	74	74
Lake	NIL	13	59
Estuary + Harbour	51	52	3
T. Sed	N.T.	N.T.	311
Stream			52
Lake			240
Estuary + Harbour			311
Biota	N.T.	N.T.	N.T.

9 Phthalate acid esters
10 Tri-aryl-phosphates
11 Phenoxyacid herbicides